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JOURNAL OF PALEONTOLOGY

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BIGHORN CONODONTS FROM WYOMING

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ABSTRACT—A considerable variety of conodonts has been recovered from two shale outcrops within the upper Bighorn Dolomite in north central Wyoming. A total of 29 species referable to 19 genera is described and illustrated. One new genus, *Pristognathus* (type: *P. bighornensis*, n. sp.) and four additional new species: *Belodina dartoni, B. kirki, Eoligonodina ulrichi*, and *Microcoelodus sweeti* are included in the fauna. The associated megafauna is definitely Late Ordovician but comparison of the conodonts with others of similar age suggests that they may be pre-Richmondian.

INTRODUCTION

PREVIOUSLY described Ordovician conodont faunas of the Rocky Mountain region are Middle Ordovician in age. The upper Bighorn conodonts recorded here were found in association with a well preserved abundant varied fauna including bryozoans, ostracodes, corals, and brachiopods that can be correlated with definite Upper Ordovician, Richmondian, or slightly older. The closest similarity of these invertebrates is with those of the Maquoketa Formation of the Upper Mississippi Valley, but they show a strong resemblance to the faunas of the type stages of the Eastern Interior as well as that of the Stony Mountain Formation near Lake Winnipeg in southern Manitoba.

This conodont fauna is the first described in association with beds which have yielded representative collections of the Arctic assemblage, a biofacies widely distributed from northern Greenland through the Southern Rockies. The strata involved here extend directly to localities in Wyoming, South Dakota, and Manitoba where the characteristic abundance of large heavily shelled molluscs and compound corals is known.

With increased knowledge, conodonts show promise of value in detailed correlation. The major difficulty is that coverage is yet insufficient in critical areas. This study is primarily an attempt to present the nature of the Upper Ordovician conodont fauna of Wyoming for comparison; some relationships are apparent.

STRATIGRAPHY

In northern Wyoming and south-central Montana, principal outcrops of the Bighorn Dolomite occur in the Absaroka Range, the Pryor and Beartooth mountains, the northeast flank of the Wind River Range and in all but the southernmost Bighorn Mountains (Richards & Nieschmidt, 1957). Outcrops have also been reported from the region south and west of the Bighorn Basin in the Owl Creek, Cedar, Rattlesnake, Wind River, Gros Ventre, Teton, Salt River ranges of Wyoming, and in the Bighole Range of southeastern Idaho (Miller, 1930).

In the subsurface of the Williston Basin of southern and eastern Montana, the Bighorn merges with the Red River and Stony Mountain formations which outcrop in the vicinity of Winnipeg, Manitoba. The Bighorn Dolomite extends eastward deeply buried in the Powder River Basin to merge with the Whitewood Dolomite which outcrops in the Black Hills of South Dakota. To the east, equivalents are found in the Galena-Maquoketa section of the Upper Mississippi Valley, but continuity is broken by the Sioux Uplift. In similar fashion, the Fremont Limestone to the south in Colorado lies within a separate province.

North of the North Fork, Powder River, on the east flank of the Bighorn Uplift, the Bighorn Formation is approximately 300 feet thick, but it thins to the south, due primarily to pre-Devono-Mississippian erosion. Richards & Nieschmidt (1957) have published an isopachous map of the Bighorn Dolomite in south-central Montana and north-central Wyoming. Thicknesses range from a maximum (436 feet) in the Bighorn Basin, near the Wyoming-Montana state line, with progressive thinning to the north and south. In western Wyoming, thicknesses of the Bighorn in the Gros Ventre, Teton, Hoback, and Snake River ranges vary from 288 to 620 feet (Wanless et al., 1955).

On the basis of gross lithology the Bighorn may be divided into three units: a thin basal sandstone member, a middle massive dolomite, and an upper thin-bedded dolomite member. A somewhat more detailed interpretation was presented by Tomlinson (1917) who, on the basis of lithologic change, divided the Bighorn Dolomite of the central Rocky Mountains into nine units. The three-fold division of the formation seems to be practicable; lithologic changes are considered in conjunction with paleontologic evidence.

Basal sandstone member.—Below the dolomite on the east flank of the Bighorn Mountains are two Ordovician sandstone units which are similar in lithology but separated from each other by a hiatus (Kirk, 1930). The upper unit is the basal sandstone of the Bighorn Formation which was named the Lander Sandstone in the Wind River Range (Miller, 1930). The lower unit is a correlative of the Middle Ordovician Harding Sandstone of Colorado (Kirk, 1930) and is here referred to as Harding. Amsden & Miller (1942) and Hose (1955) report about 70 feet of lower Bighorn sandstone cropping out on the North Fork of Crazy Woman Creek and correlate all but the upper few feet with the Harding Sandstone. At this location, the Harding is dominantly light-gray and relatively fine-grained in the lower 48 feet but consists of an indurated medium-grained quartz sandstone in the upper 12 feet. Darton (1906b) noted that the lower sandstone (Harding) is absent in the Shell and Cedar Creek areas on the west flank of the Bighorns, and only four feet thick at Bear Rocks, an Ordovician outlier located just west of the head waters of Cedar Creek.

The ostracoderm plates so common in the Harding were discovered in 1892 by Walcott. They have been frequently mentioned in the literature and described in some detail by Bryant (1937) and by Ørvig (1958). Fragmentary material from the upper Bighorn comparable to that figured from the Black Hills (Furnish et al., 1936, pl. 1, fig. 4, pl. 2, fig. 2) has been noted in a variety of Middle and Upper Ordovician localities. Some few plates similar to Harding forms which occur in the Lander Sandstone are probably reworked. Although there is some doubt about the holotype of *Pycnaspis splendens* Ørvig, it appears to have been derived from uppermost Bighorn.

The type locality of the Lander Sandstone is on the northeast slope of the Wind River Mountains where it varies from a few inches to 10 feet in thickness (Branson & Branson, 1941). Typically it is a slightly calcareous ferruginous light-pink quartzitic sandstone (Miller, 1932). Miller also noted that a few inches of thin-bedded grayish-green calcareous shale containing blocks of limestone and sandstone occur at the base of the unit immediately above the irregular surface of the underlying Gallatin Formation. The Harding equivalent is not present in western Wyoming. Outcrops of the Lander on the east flank of the Bighorn Mountains are 2 to 8 feet thick and composed of pink to dark red, medium-grained dolomitic sandstone. Large fossils, such as *Halysites*, *Receptaculites*, *Maclurites*, and

Cyclendoceras are characteristic and abundant. This unit is absent in some areas of the west flank.

Middle massive dolomite member.—This resistant massive cliff-forming unit is present throughout the outcrop area. It is composed of mottled buff dolomite which weathers unevenly. The thickness of this member varies from area to area. It ranges from 210 to 260 feet in thickness in the Beartooth Mountains, Absaroka Range, western flank of the Bighorn Mountains, and the adjacent Bighorn Basin (Richards & Nieschmidt, 1957), but exeeds 700 feet in thickness in the Snake River Range (Wanless et al., pl. 16).

Upper thin-bedded dolomite member.—According to Darton (1906d), "the upper portion of the formation consists of limestone softer and purer than those below; the bedding is thinner, color white to gray, and parts of the rock are very compact or fine-grained, often resembling lithographic limestone." He also noted that this member is from 75 to over 100 feet in thickness in the northern Bighorns and that it contains massive beds 15 to 25 feet thick that are lithologically similar to the underlying massive member. Blackwelder (1918) applied the name Leigh Dolomite member to this unit for outcrops on the west slope of Dinwoody Canyon in the Wind River Range.

Darton (1906d) noted that in the canyon of the South Fork Rock Creek on the east flank of the Bighorn Mountains, the Leigh Member contains a good exposure of an extremely fossiliferous nonresistant calcareous shale and limestone. The zone is some 5 to 10 feet thick and occurs approximately 10 feet below the top of the formation. This zone was also located at an outcrop of the Leigh member on the top of the hogback just south of Johnson Creek.

On the west flank of the Bighorns, a similar abundant occurrence of fossils has been found by Ted R. Larimer, a graduate student. This locality is on the south side of Shell Canyon (NE¼, sec. 16, T. 53 N., R. 90 W.) about 300 feet above the Gallatin contact and some 50 feet below the Devonian Jefferson Formation; Darton (1906b, p. 4) mentions upper Bighorn collections from the same general vicinity. The sporadic nature of these exposures is believed to be primarily a result of the nonresistant nature of the beds. Indications of the lithology and fauna can be found at a number of other localities on both sides of the range.

AGE AND CORRELATIONS

Arctic Fauna.—The fauna of the Bighorn Formation is representative of a general fauna which is contained in Ordovician rocks that once extended over a large part of northern and western North America. Due to the fauna's prominence in Arctic and subarctic North America, it has been referred to as the "Arctic fauna" (Miller et al., 1954). Southern limits are believed to extend as far south as Anticosti Island in the East, into northern Iowa in the Upper Mississippi Valley, and it is well represented in the Cordilleran region as far south as northern Mexico (Sonora). The same fauna has been recognized in many localities of the District of Franklin, northern Canada, as well as in the Seward Peninsula of Alaska (Miller et al., 1954). In addition to these occurrences in North America, some of the characteristic elements of this assemblage are known in northern Eurasia.

Rocks containing this fauna have been described as deposited in an Ordovician sea that had direct Arctic connections; open migration between this sea and the one that engulfed eastern United States was restricted (Miller, 1930). As a result of the concurrent existence of these biologic domains, faunal differences developed in contemporaneous deposits, and therefore detailed correlation between the Ordovician of the Cordilleran Region and similar strata in eastern United States is difficult and open to controversy. Compared to faunal assemblages from the type areas of the North American Ordovician, the Arctic fauna contains a mixture of Mohawkian and Cincinnatian forms.

The Arctic fauna is characterized by large compound corals, heavily shelled molluscs, and *Receptaculites*. For the most part, these forms are also characteristic of the Bighorn fauna. However, on the South Fork of Rock Creek on the east flank of the Bighorn Mountains, the Leigh Member contains a fauna which is in striking contrast to the usual Bighorn (Arctic) fauna. A shale and limestone zone at that location contains a

Cincinnatian fauna composed of horn corals, bryozoans, and brachiopods, which is similar to that of the type Upper Ordovician of Eastern Interior United States (Duncan, 1957; Ross, 1957). Conodonts are rare and poorly preserved in the dolomites of the Bighorn, but they are common and moderately well-preserved in this particular limestone and shale zone.

Occurrence of the Rock Creek fauna in a lithology that is atypical of the Bighorn Formation is of special significance. The presence of a limestone and shale unit, bearing a characteristic Cincinnatian fauna, in a sequence of dolomites which contain the Arctic fauna indicates a direct relationship between lithofacies and the enclosed fauna. This also suggests that the barrier between eastern United States and the areas occupied by strata containing the Arctic fauna was not a physical one but rather a zone of transition between two different environments of deposition. Thus, when conditions of deposition in the Cordilleran region were similar to those in eastern United States, like faunas developed.

Correlation.—The Bighorn Formation has received much attention from stratigraphic paleontologists (Ulrich *in* Darton, 1906d; Miller, 1930; Kirk, 1930; Foerste, 1935; Kay, 1935). Several correlations have been proposed and some now generally agreed upon.

Because of the occurrence of fish plates in the 60 to 80 feet of lower sandstone, Darton (1906a) correlated this unit with the Harding Sandstone of Colorado, which he considered to be Black River in age. Similarly, Kirk (1930) recognized two units in the sandstone sequence of the Bighorn and Bridger mountains. He correlated the lower unit with the Harding Sandstone and considered the upper unit to represent the true basal sandstone of the Bighorn Dolomite. Miller & Amsden (1942) found that the lower sandstone sequence contains two conodont faunas. They correlated the older fauna with that of the Harding Sandstone. The Harding varies in thickness and is present only in certain outcrops of the Bighorn Formation. Kirk (1930) considered the Harding to be Middle Ordovician. Studies of the type Harding megafauna and microfauna indicate that it is Black River in age. Sweet (1955) correlated the Harding with the Glenwood Shale of Minnesota, parts of the Plattin Formation of Missouri, and the lower Whitewood (Icebox Shale) of South Dakota. Recently discovered Icebox graptolites have been identified by C. E. Decker as *Diplograptus*, *Cryptograptus*, and *Climacograptus* of definitely Middle Ordovician (Normanskill) age. Baillie (1952) stated that the Winnipeg Formation can be traced from its outcrop area in Manitoba south through the subsurface to the "Whitewood Shales" of the Black Hills. The conodont fauna of the subsurface Winnipeg is also believed to be Middle Ordovician (Holland & Waldren, 1955). However, the ostracoderms *Pycnaspis* and *Eriptychius* recorded by Ørvig (1958) from subsurface Winnipeg are stated to resemble those from the upper Bighorn as well as those from the lower Whitewood, but are believed to be different from the true Harding material.

In the Wind River Range, the Harding is absent from the section but there is usually a few feet of sandstone below the dolomite which occupies the same stratigraphic position as the basal sandstone of the Bighorn Mountains. This unit is very fossiliferous and cephalopods are the most striking and abundant faunal element. (Miller, 1930) applied the name Lander to these deposits and, on the basis of detailed faunal studies, he concluded the age to be Richmondian. However, as early as 1930, Kirk in discussing the Harding Formation proposed a post-Trenton, pre-Richmondian age for the basal sandstone of the Bighorns. Foerste (1935) noted that certain faunal assemblages suggest that the Stewartville Dolomite in the Upper Mississippi is of approximately the same age as the Lander Sandstone. Kay (1935), stated that the faunal similarities between the Stewartville Dolomite of Iowa and northern Illinois and the Bighorn Formation, suggested that all the Bighorn may be Trenton in age. Recent work by Flower (*e.g.* 1957) indicates that the Lander fauna is "Red River" in character and of late Trentonian or Edenian age. Flower's interpretation of the equivalency of these two stage names removes much of the basic correlation problem that has existed for thirty years.

Fossils are relatively rare and poorly pre-

served in the lower and middle Bighorn dolomite. Securing specimens is made more difficult by the cliff-forming nature of this unit. Consequently, little detailed information is available about the fauna of this member and suggestions as to its age are, for the most part, inferences based on its stratigraphic position. However, the underlying Lander Member is considered to be an introductory clastic phase of the massive dolomite, and correlations based on the Lander fauna are valid for at least the lower part of this formation. Flower (1957; 1958) suggests that the massive member may contain some Richmondian strata in the upper part.

Fossils collected from the upper thin bedded dolomite member at various localities in the Bighorn Mountains were studied by Ulrich (Darton, 1906c) who considered them to be Richmondian in age. However, Miller et al. (1954) stated that because the majority of the Bighorn species suggest a correlation with Trenton and a considerable remainder show Richmond affinities, the containing strata are probably younger than Trenton and older than Richmond (Eden and/or Maysville). Kirk (1925) had apparently been the first to reach this conclusion. The relatively diversified and advanced coral fauna of the lower Bighorn has been interpreted by Duncan (1956) as being indicative of Late (probably early Late) Ordovician age. Twenhofel et al. (1954) have listed the Bighorn Formation as Richmondian.

It should be emphasized that more than one faunal zone can be recognized in the Bighorn Formation. Flower's (1957) Red River Stage is synonymous with the Arctic pre-Richmond Cincinnatian. In Wyoming, this fauna is best known from the Lander Sandstone of the Wind River Mountains, a basal clastic phase of the Bighorn. Within the Bighorns, this unit occurs, and it carries the characteristic cephalopod genera: *Cyclendoceras*, *Cyrtogomphoceras*, *Kochoceras*, *Lambeoceras*, etc. Nautiloids described from the northwest flank of the Bighorn uplift were derived from a different part of the formation at least 100 feet higher stratigraphically than the Lander (Foerste, 1935; Miller & Carrier, 1942). These fossils occur in an apparent Selkirk (upper Red River) equivalent with a younger aspect than Lander-Dog Head (lower Red River). In the vicinity of Hunt and Medicine mountains, the source of most of the fossils, the section is exposed in a vertical cliff; some few of the originals were found in talus blocks at the base, but others came from near the crest of the escarpment. Poorly preserved actinoceratoid siphuncles (*Actinoceras* and *Armenoceras*) have been found abundantly within ledges at the top of the cliff. The large *Apsidoceras* is also represented *in situ*, together with a number of other nautiloids apparently more or less restricted to the middle Bighorn. In this region *Armenoceras* may be regarded as an indicator of upper Cincinnatian, although not an index. This genus has been found in the Maquoketa Formation, and is characteristic of both the upper Red River (Selkirk) and Stony Mountain formations.

The upper dolomites were correlated with the Stony Mountain Formation and the Shamattawa Limestone of south central Canada by Miller (1930); lithology and general faunal aspect of the shales in the Stony Mountain are the same as those on South Fork Rock Creek. Ross (1957) suggested the equivalence of the upper Bighorn and the English Head and Vauréal formations of Anticosti Island. He further noted (p. 456) that the brachiopod, coral, and bryozoan fauna contained in the red shaly and silty beds of the upper Bighorn Dolomite is strikingly similar to that of the Maquoketa Shale of Iowa. Sweet's (1954) faunal collections from a shale at the base of the upper Fremont (Priest Canyon Member) in central Colorado are very similar and suggest close relationship.

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CONODONT LOCALITIES

Locality 1.—Approximately 300 feet of the Bighorn Dolomite is exposed in the mountain front near the base of the canyon

on the South Fork Rock Creek, center, N½, NE¼, SW¼, SW¼, sec. 25, T. 52 N., R. 84 W., Johnson County, Wyoming, 13 miles northwest of Buffalo. Samples were collected from 5 to 10 feet of thin limestone beds interbedded with red and gray calcareous shales. This zone occurs near the top of the Leigh Dolomite (below some 75 feet of probable Devonian with siltstone and dolomite). Well preserved brachiopods and corals are abundant and tend to weather out of the enclosing shale and limestone slabs. The lower part of the section is characterized by thin beds (2 to 3 inches) of very coarse detrital limestone. This locality has been a classic one for many years. It is the locality from which Darton (1906c) collected many of the specimens referred to in his report. Also, fossils from this locality have been figured by Duncan (1956, 1957) and Ross (1957).

Locality 2.—Bulk samples of limestone and red calcareous shale were collected from a low saddle in the crest of the main hogback immediately south of Johnson Creek (NW¼, SW¼, NW¼, sec. 20, T. 51 N., R. 83 W.) Johnson County, Wyoming. The zone from which samples were taken is lithologically similar to the limestone and shale on South Fork Rock Creek and occupies the same stratigraphic position. The Bighorn Dolomite dips steeply in this area and the strata under discussion are poorly exposed between layers of the resistant dolomite. The irregularity of the shale exposure suggests that it may represent a solution fill, for none of the fossiliferous limestone slabs appeared to be in place. This locality was originally discovered by Richard A. Hoppin.

OCCURRENCE OF CONODONTS

Conodont bearing limestone and shale samples were secured at only two localities, a limestone and shale zone in the Leigh Member that is exposed on the South Fork Rock Creek and (about 5 miles to the south) near Johnson Creek, both in the steeply dipping east flank of the Bighorns. Limestone samples were broken into fragments that measured approximately 1 cm. in diameter and digested in a 15 per cent solution of acetic acid. The residue was screened, washed, and dried. In addition to conodonts, the residue contains earthy masses of hematite, undigested limestone, a few quartz grains and calcite crystals. Bryozoans, ostracodes, fish plates, gastropods, and crinoid columnals are common constituents. The red calcareous shales were disaggregated by warm water and washed through a series of screens. The resulting residue is similar to the limestone residue, but hematite forms thin incrustations on all particles.

Conodont specimens from shales of both localities are, for the most part, broken and abraded but those from the limestones are much better preserved. Limestone from the South Fork Rock Creek provided the most productive samples. Even at this locality the conodonts which occur in the limestones are not uniformly distributed; however, no quantitative data was assembled relative to this observation. Some of the forms which were collected from the Rock Creek locality were found to be lacking in the Johnson Creek collection. This is probably not significant in that the less extensive collections from that locality would likely explain the difference.

The conodont fauna of the Leigh Member includes 29 species which are referred to 19 genera; a few hundred identifiable specimens were collected. *Panderodus* is the most abundant genus in the fauna. *Erismodus*, *Lonchodus*, and *Keislognathus* are represented by single specimens only. All specimens are translucent, varying in color from light yellowish brown to light gray and white.

Comparison with other Upper Ordovician faunas.—In the United States, Upper Ordovician conodonts from the following stratigraphic units have been studied and reported in the literature: Maquoketa Formation of Iowa and Kansas, Thebes Sandstone of Missouri, Maravillas Formation of the Marathon Basin, Texas, and from the Richmond Group of Kentucky and Indiana. Conodonts from the Dubuque Member and the upper part of the Stewartville Member of the Galena Formation in northeastern Iowa appear to have Upper Ordovician affinities. A few forms are known from the Shamattawa Limestone near Hudson Bay and the Stony Mountain Shale near Lake Winnipeg. Upper Ordovician conodonts reported from Great Britain include those from the Gelli-grin and Pen-y-garnedd Limestones of North Wales and the

Keisley Limestone of Westmorland, England.

Branson & Mehl (1933) described the Maquoketa-Thebes fauna which they considered to be Upper Maysville-Lower Richmond in age. Study of the conodonts of the Richmond Group by Branson et al. (1951) revealed marked differences between it and the Maquoketa fauna. They cited major differences such as: the absence of *Ambalodus* and *Amorphognathus* from the Richmond fauna, plus the presence of *Zygognathus* and *Rhipidognathus*, and suggested these and other differences could be best accounted for by considering the Maquoketa to be pre-Richmond in age. Recent study of the Maquoketa of Iowa indicates a pre-Richmond age for the lowest member, but younger members may be Richmond or slightly older (Glenister, 1957). Glenister based this interpretation, in part, on the presence of *Ambalodus* and *Amorphognathus* in only the lowermost member. It was pointed out, however, that the lower unit produced the most substantial fauna, and ecological factors may account for absence of these genera in the younger members. Graves & Ellison (1941) described the conodonts from the Maravillas Formation which is considered to be Richmond in age (Twenhofel et al., 1954). The Dubuque fauna is most probably Eden or Maysville in age (Ethington, 1959). Rhodes (1953) studied the conodont faunas of the Gelli-grin and Pen-y-garnedd limestones, Upper Caradocian in age. He noted that the Gelli-grin fauna was closer to the faunas of the Maquoketa-Thebes and the Maravillas than to that of the Richmond Group. This conclusion was based on the fact that the Richmond fauna does not contain *Ambalodus* and *Amorphognathus*, but does contain

TABLE 1—DISTRIBUTION OF UPPER BIGHORN CONODONT GENERA

Genus	FORMATION											
	Pre-Cincinnatian Formations	Upper Bighorn Dolomite Wyoming	Upper Galena Formation Iowa, Minnesota	Maquoketa Formation Iowa, Minnesota	Maravillas Formation West Texas	Thebes Sandstone Missouri	Keisley Limestone Westmorland	Pen-y-garnedd Limestone North Wales	Gelli-grin Limestone North Wales	Stony Mountain Shale Southern Manitoba	Shamattawa Limestone Northern Manitoba	Richmond Group Kentucky
Ambalodus	X	X	X	X	X	X	X	X	X	?		
Amorphognathus	X	X	X	X	X	X	X	X	X	X		
Belodina	X	X	X	X	X	X				X	X	
Cordylodus	X	X	X	X	X	X	X			X	X	
Drepanodus	X	X	X	X	X	X	X	X	X	X	X	X
Oistodus	X	X	X	X	X		X	X		X	X	
Panderodus	X	X	X	X	X		X	X	X	X	X	X
Trichonodella	X	X	X	X	X	X	X	X	X	X	X	X
Ozarkodina	X	X	X	X	X	X				X	X	
Cyrtoniodus	X	X	X	X							X	
Keislognathus		?	X				X					
Tetraprioniodus	X	X	X				X					
Gyrognathus		X	X						X		X	
Lonchodus	X	X						X	X			
Eoligonodina		X	X							X	X	X
Microcoelodus	X	X					?					X
Oulodus	X	X									X	?
Erismodus	X	?										
Pristognathus		X								X		

Rhipidognathus and *Zygognathus*, two genera that have not been found in any other Upper Ordovician fauna. He also noted that the Gelli-grin fauna differed from the Richmond in its lack of variety of species of *Panderodus*. Rhodes (1955) concluded that the conodonts of the Keisley Limestone of north Wales are older than Richmond but younger than the Gelli-grin, Pen-y-garnedd, Maquoketa-Thebes, and the Maravillas faunas.

Holland & Waldren (1955) have reported the occurrence of conodonts in well samples of the Winnipeg Sandstone at a depth of 11,000 feet. They placed their specimens in 13 species, and 6 genera. *Microcoelodus* and *Acontiodus* were cited as evidence for a pre-Cincinnatian (Black River or Chazyan) age for this fauna.

Table 1 was constructed to facilitate faunal comparisons and in an effort to detect any faunal trends that might exist. Several points of comparison that are indicated by the table and comments concerning their possible significance are outlined below:

1. As far as it is known, the fauna of the Richmond Group is the most distinctive of the associations listed. Absence of *Ambalodus*, *Amorphognathus*, *Belodina*, *Cordylodus*, *Oistodus*, and *Ozarkodina*, all of which are common members of the remaining faunas, distinguishes the Richmond fauna from the others. The lack of *Ambalodus* and *Amorphognathus*, which are reported in all the Upper Ordovician faunas except this one, is particularly significant. The Leigh Member fauna contains all six of the common Upper Ordovician genera which have not been reported from the Richmond. In addition to these differences, the Leigh fauna lacks such forms as *Aphelognathus*, *Rhipidognathus* and *Zygognathus*, which are common genera of the Richmond. It appears probable that the Leigh Member conodont fauna is pre-Richmond in age.
2. The presence of *Ambalodus*, *Gyrognathus*, and *Eoligonodina* in the Leigh Member suggests a post-Trenton age.
3. *Belodina* and *Ozarkodina* are present in all but the Richmond and the British Upper Ordovician faunas. The occurrence of these genera may prove to be significant when more information is available.
4. *Drepanodus* and *Trichonodella* are present in all of the faunas that are compared here. Individual species of these genera may prove to be stratigraphically restricted and therefore useful in dating Ordovician faunas when more studies have been made.
5. Forty-four conodont genera have been reported from Upper Ordovician strata. Of these, eighteen occur in only one of

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EXPLANATION OF PLATE 31

All specimens are from the limestone and shale zone in the upper Bighorn Dolomite on the east flank of the Bighorn uplift, Johnson County, Wyoming.

FIG. *1*—*Panderodus intermedius* (Branson, Mehl & Branson). ×20.
2—*P. gracilis* (Branson & Mehl). ×45.
3—*P. feulneri* (Glenister). ×45.
4—*P. panderi* (Stauffer). ×45.
5—*Oistodus excelsus* Stauffer. ×60.
6—*O. inclinatus* Branson & Mehl. ×45.
7—*Drepanodus suberectus* (Branson & Mehl). ×25.
8—*D. homocurvatus* Lindström. ×60.
9—*Cyrtoniodus complicatus* Stauffer. ×45.
10—*Lonchodus spinuliferus* Stauffer. ×70.
11—*Belodina dispansa* (Glenister). ×85.
12,13—*B. kirki* Stone & Furnish, n. sp. ×70.
14—*B. compressa* (Branson & Mehl). ×60.
15—*B. dartoni* Stone & Furnish, n. sp. ×70.
16,17—*B. profunda* (Branson & Mehl). ×85.
18—*Microcoelodus sweeti* Stone & Furnish, n. sp. ×45.

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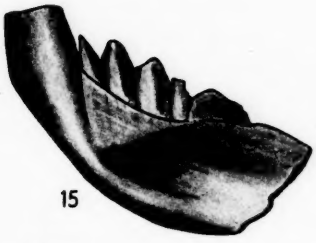
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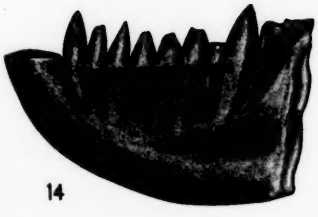
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the ten formations from which conodonts have been described. The fact that each individual fauna contains distinctive genera may prove to be an overall faunal characteristic for conodonts of this period, or it may indicate the need for additional studies.

In conclusion, the conodont fauna of the Leigh Member of the Bighorn Dolomite is significantly different from that of the Richmond but quite similar to North American and European faunas that are considered to be Eden-Maysville equivalents. A Maysvillian age seems most likely for the upper Bighorn, by a process of elimination. No more nearly precise correlation of these Upper Ordovician conodonts seems justified at present.

SYSTEMATIC DESCRIPTIONS

Genus AMBALODUS Branson & Mehl, 1933
Type species: *A. triangularis* Branson & Mehl, 1933

AMBALODUS TRIANGULARIS Branson & Mehl
Pl. 32, fig. 3

Ambalodus triangularis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 128, pl. 10, figs. 35–37; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 62; RHODES, 1953, Roy. Soc. London Phil. Trans., s.B., no. 647, v. 237, p. 280, pl. 20, figs. 28–31; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 732, pl. 88, figs. 20,21.

The basal segment of this form is a crescent-shaped aborally excavated platform consisting of an anterior bar and a shorter posterior bar. The oral surface is convex upward. An irregular lip or parapet is formed on the margins of both the anterior and posterior bars. A denticulate parapet composed of a single row of fused denticles is medial in position on the posterior bar and close to the convex margin on the anterior bar. There are approximately four denticles on the posterior bar and eight on the anterior bar. A stout cusp is directed posteriorly, rounded on its outer surface, and nearly flat on its inner surface. The denticulate parapets are fused to the base of the cusp both anteriorly and posteriorly. Carinae extend upward from these junctions and become less conspicuous near the tip of the cusp. The anterior margin forms a flange that merges with the denticulate parapet of the anterior bar. An outer lateral process is platform-like and has a medial row of fused denticles. On most of the specimens studied, an angular re-entrant is present on the inner side of the base at the junction of the anterior and posterior bars. Commonly this feature is well developed and accompanied by a narrow depression extending from the apex of the re-entrant toward the cusp.

Remarks.—Three cotypes figured by Branson & Mehl are somewhat fragmentary but agree closely with Bighorn specimens. Those authors described the outer lateral process but the feature was not clearly illustrated. Rhodes (1953, 1955) figured closely similar forms, and he presented a diagrammatic interpretation. Comparison with Maquoketa specimens described by Glenister (1957) indicates that they are

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EXPLANATION OF PLATE 32

All specimens are from the limestone and shale zone in the upper Bighorn Dolomite on the east flank of the Bighorn uplift, Johnson County, Wyoming.

FIGS. *1,2—Ozarkodina? delecta* Stauffer. ×70.
3—Ambalodus triangularis Branson & Mehl. ×80.
4,5—Oulodus mediocris Branson & Mehl. ×45.
6—Keislognathus sp. ×80.
7,8—Pristognathus bighornensis Stone & Furnish, n. gen., n. sp. ×45.
9—Gyrognathus elongata Rhodes. ×45.
10—Cordylodus plattinensis Branson & Mehl. ×70.
11—Erismodus tantus Stauffer. ×45.
12—Amorphognathus ordovicica Branson & Mehl. ×75.
13—Tetraprioniodus superbus (Rhodes). ×75.
14—Trichonodella recurva (Branson & Mehl). ×45.
15—T. barbara (Stauffer). ×65.
16-18—Eoligonodina ulrichi Stone & Furnish, n. sp. ×65.

conspecific with the Bighorn forms. This species occurs in the Thebes Sandstone of Missouri, the Maravillas Formation of Texas, and the Maquoketa Formation of Iowa, Minnesota, and Kansas. *Ambalodus triangularis* has been reported from the Gelli-grin and Pen-y-garnedd limestones of Wales. All of these occurrences are from rocks regarded as Upper Ordovician in age.

Repository.—Figured hypotype, S.U.I. 10100; unfigured specimens, S.U.I. 10101.

Genus AMORPHOGNATHUS Branson & Mehl, 1933
Type species: *A. ordovicica* Branson & Mehl, 1933

AMORPHOGNATHUS ORDOVICICA Branson & Mehl
Pl. 32, fig. 12

Amorphognathus ordovicica BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 126–127, pl. 10, fig. 38; FAY, 1952, Univ. Kansas Paleont., Vertebrata art. 3, p. 63; RHODES, 1953, Royal Soc. London, Phil. Trans., s. B no. 647, v. 237, p. 283, pl. 20, figs. 47–49.

Complex platform-like dental units consisting of three segments: an outer segment consisting of a branching bar with the anterior limb longer than the posterior; a medial segment having a slender tapering anterior bar and a broad blunt posterior bar; an inner segment with two small subequal limbs. The aboral surface is deeply excavated and moderately arched. Oral surface is smooth. Bars have oral marginal furrows and their medial oral surfaces are convex upward and surmounted by a single row of fused denticles.

Remarks.—All of the specimens studied are incomplete but collectively they show the characteristics of the species as defined by Branson & Mehl. The figured specimen lacks only the inner segment. This species is relatively common in the upper Bighorn shales and limestones of Johnson County, Wyoming.

Repository.—Figured hypotype, S.U.I. 10102; unfigured specimens, S.U.I. 10103.

Genus BELODINA Ethington, 1959
Type species: *Belodus grandis* Stauffer, 1935

BELODINA COMPRESSA (Branson & Mehl)
Pl. 31, fig. 14

Belodus compressus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 114, pl. 9, figs. 15,16; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 67.

Remarks.—One well-preserved specimen which is closely similar to the type material was recovered. This species has been described from the Plattin and Kimmswick limestones of Missouri and from the Whitewood shale of South Dakota. It was recovered from the limestone of the limestone and shale zone, Leigh Member, Bighorn Dolomite which crops out on the South Fork Rock Creek in Johnson County, Wyoming.

Repository.—The figured specimen was lost during the preparation of illustrations.

BELODINA DARTONI Stone & Furnish, n. sp.
Pl. 31, fig. 15

In this species the basal cone is bilaterally symmetrical, somewhat angular in form and laterally compressed. The basal cone is expanded laterally at its base, sharply constricted at about mid-length, moderately expanded to the height of the anteriormost denticle and tapering from there to its tip. The oral surface of the cone is straight and set with approximately four slender confluent peg-like denticles that are directed orally at an angle of slightly less than 90°. The denticles become progressively shorter posteriorly and are partially covered by a triangular shaped sheath. The transverse cross-section of the base is relatively narrow throughout. A basal cavity extends anteriorly from the base to a point directly below the anteriormost denticle.

Remarks.—This description is based on only two incomplete specimens and, consequently, the basal portion cannot be adequately described.

Repository.—Figured holotype, S.U.I. 10108; unfigured paratype, S.U.I. 10109.

BELODINA DISPANSA (Glenister)
Pl. 31, fig. 11

Belodus dispansus GLENISTER, 1957, Jour. Paleontology, v. 31, p. 729–730, pl. 88, figs. 14,15.

Remarks.—The upper Bighorn specimens are closely similar to the type material. However, longitudinal striations along the lateral surfaces which are mentioned in Glenister's description were not observed on the Bighorn forms.

Occurrence.—Wyoming specimens were

recovered from upper Bighorn limestones which crop out along the South Fork of Rock Creek, in Johnson County.

Repository.—Figured hypotype, S.U.I. 10104.

BELODINA KIRKI Stone & Furnish, n. sp.
Pl. 31, figs. 12,13

The basal cone of this species is broadly rounded on the inferior margin and curves orally with increasing abruptness toward the anterior end. The unit is markedly asymmetrical. A flange which extends to the tip of the cone is developed on the outer side of the basal cone just forward of the base and near the inferior margin. This flange is more prominent in the antero-oral region of the basal cone where it is directed posteriorly. Another flange originates in a similar position on the inner side. It is prominent posteriorly but less conspicuous in the oral region where it is anterior and parallel to the posterior edge of the basal cone. A small ridge originates on the inner surface of the base at mid-length and extends anteriorly to the tip of the basal cone. This ridge becomes the posterior margin of the basal cone. The transverse cross-section of the base is narrow orally; it expands at mid-height and narrows toward the blunt inferior edge. The oral margin is set with approximately six confluent peg-like denticles. A basal flange occupies the postero-oral margin of the basal cone, and its anterior edge is confluent with the posterior denticle.

Remarks.—Only a single specimen was recovered. This species is similar to *Belodina inclinatus* Branson & Mehl, 1933, (p. 125, 126, pl. 10, fig. 24) but the two differ in that *B. inclinatus* is flanged on only one side and has inclined denticles.

Occurrence.—Shale and limestone zone in the upper Bighorn Formation, at the South Fork of Rock Creek, Johnson County, Wyoming.

Repository.—Figured holotype, S.U.I. 10107.

BELODINA PROFUNDA (Branson & Mehl)
Pl. 31, figs. 16,17

Belodus profundus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 125, pl. 10, fig. 25; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 67.

Remarks.—Bighorn specimens vary in amount of curvature and lateral flexure of the basal cone as well as the cross-sectional configuration of the base. Several large well preserved specimens that had but two denticles were recovered, whereas the types figured by Branson & Mehl have three denticles.

Repository.—Figured hypotypes, S.U.I. 10105; unfigured specimens, S.U.I. 10106.

Genus CORDYLODUS Pander, 1856
Type species: *C. angulatus* Pander, 1856
CORDYLODUS PLATTINENSIS Branson & Mehl
Pl. 32, fig. 10

Cordylodus plattinensis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 110,117, pl. 8, figs. 34,36; FAY, 1953, Univ. Kansas Paleont. Contrib., Vertebrata, art 3, p. 82.

Remarks.—Practically all of the upper Bighorn specimens have been broken and abraded. In most cases the denticles are broken near the base. The basal portion of the unit is either broken or absent. Collectively these specimens appear specifically identical to those originally described by Branson & Mehl. This species has been found in Wyoming, Missouri, Oklahoma, Texas, and South Dakota in strata that are considered to be Middle or Upper Ordovician in age.

Repository.—Figured hypotype, S.U.I. 10110; unfigured specimens, S.U.I. 10111.

Genus CYRTONIODUS Stauffer, 1935
Type species: *C. complicatus* Stauffer, 1935
CYRTONIODUS COMPLICATUS Stauffer
Pl. 31, fig. 9

Cyrtoniodus complicatus STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 140, 158, pl. 11, figs. 44,46,48–51; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 85; RHODES, 1953, Royal Soc. London, Phil. Trans., s.B., no. 647, v. 237, p. 302, pl. 22, figs. 193–196; SWEET, 1955, Jour. Paleontology, v. 29, p. 132, pl. 2, fig. 3; GLENISTER, 1957, ibid., v. 31, p. 732, pl. 88, fig. 16.

Remarks.—*Cyrtoniodus complicatus* is a common species in the upper Bighorn fauna. Most of the specimens are incomplete, but they agree with Rhodes' emended description. This species has been previously reported from the upper Glenwood beds and Decorah Shale in Minnesota, the Spechts Ferry in Iowa, the lower Bighorn Dolomite

in Wyoming, the Harding Sandstone in Colorado, and Llandeilo Limestone of Wales.

Repository.—Figured hypotype, S.U.I. 10112; unfigured specimens, S.U.I. 10113.

Genus DREPANODUS Pander, 1856
Type species: *D. arcuatus* Pander, 1856
DREPANODUS HOMOCURVATUS Lindström
Pl. 31, fig. 8

Oistodus curvatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 110, pl. 12, figs. 20,23,24,27,29,30,36; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 134, 135; BRANSON ET AL., 1951, Jour. Paleontology, v. 25, p. 9, pl. 2 figs. 7–10; RHODES, 1953, Royal Soc. London, Phil. Trans. s.B., no. 647, v. 237, p. 295, pl. 21, figs. 89,90, pl. 22, figs. 157–161; SWEET, 1955, Jour. Paleontology, v. 29, p. 251,252, pl. 28, fig. 7.

Drepanodus homocurvatus LINDSTRÖM, 1954, Geol. Fören. Stockholm, Förhandl., Bd. 76, H. 4, p. 563, pl. 2, figs. 23,24,39; GLENISTER, 1957, Jour. Paleontology, v. 37, p. 785, pl. 86, fig. 13; pl. 87, figs. 1–6,8.

Remarks.—This species is very common in the upper Bighorn fauna and includes a variety of forms. The anterior edges of some of the specimens were flattened, depressed, and in some cases flexed laterally, whereas in others this feature was not apparent. The amount of curvature and lateral flexure of the cusp are variable and gradational in character. *D. homocurvatus* is a common Ordovician species, and has been reported from rocks of Lower to Upper Ordovician age.

Repository.—Figured hypotype, S.U.I. 10114; unfigured specimens, S.U.I. 10115.

DREPANODUS SUBERECTUS (Branson & Mehl)
Pl. 31, fig. 7

Oistodus suberectus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 111, pl. 9, fig. 7; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 136; BRANSON ET AL., 1951, Jour. Paleontology, v. 25, p. 8,9; RHODES, 1953, Royal Soc. London, Phil. Trans., s.B., no. 647, v. 237, p. 295, pl. 21, figs. 97,98, pl. 22, figs. 166,167; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 725,727, pl. 86, figs. 12,14.

Drepanodus suberectus LINDSTRÖM, 1954, Geol. Fören. Stockholm, Förhandl, Bd. 76, H. 4, p. 572,573.

Remarks.—*Drepanodus suberectus* is very common in the upper Bighorn fauna and many robust forms were collected. Specimens showed but little variation in form in these collections. This species has been reported from many localities in the Upper Mississippi Valley and in Colorado and Wyoming. It has also been described from England. Stratigraphically, *D. suberectus* ranges from Lower to Upper Ordovician.

Repository.—Figured hypotype, S.U.I. 10129; unfigured specimens, S.U.I. 10130.

Genus EOLIGONODINA Branson, Mehl & Branson, 1951
Type species: *E. robusta* Branson, Mehl & Branson, 1951
EOLIGONODINA ULRICHI Stone & Furnish, n.sp.
Pl. 32, figs. 16-18

The terminal denticle is long, slender, recurved above its base, laterally compressed, and twisted longitudinally toward the outer side. Posterior bar is not compressed but is approximately as wide as it is deep. It is aborally excavated throughout and set with approximately five stout subcircular denticles that are crowded but discrete. The terminal denticle is extended aborally and posteriorly on the inner side as a denticulate bar that is inclined approximately 30° to the posterior bar. This aboral bar is approximately as long as the posterior bar and set with about four subcircular stout denticles that are relatively far apart anteriorly but more closely spaced near the posterior end. A narrow furrow is formed on the inner side of the aboral bar by junction of the basal sheath and the outer inferior edge of the bar surface. Basal cavity is deep and is located beneath the oral bar but lateral to the aboral bar.

Remarks.—Rhodes (1953) discussed the similarities of *Ligonodina* and *Eoligonodina*. He concluded that the differences were insufficient to justify generic separation. In discussing this genus, Branson et al. (1951) noted that *Ligonodina* did not possess a "deeply excavated thin walled base in the terminal fang." The authors feel that this feature is a worthwhile basis for distinction and therefore consider *Eoligonodina* a valid genus. *Belodus* sp. from the Maravillas Formation (Graves & Ellison, 1941, pl. 3, fig. 14) closely resembles the form that is here described as *E. ulrichi*.

Repository.—Figured syntypes, S.U.I.

10116, 10117; unfigured specimens, S.U.I. 10118.

Genus ERISMODUS Branson & Mehl, 1933
Type species: *E. typus* Branson & Mehl,1933
ERISMODUS TANTUS Stauffer
Pl. 32, fig. 11

Erismodus tantus STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 143,159, pl. 12, fig. 7; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 91.

Complex dental units consisting of an anterior denticulate bar, a posterior denticulate bar, and an apical cone. The anterior bar is set with approximately four stout, laterally compressed, slightly recurved denticles. The posterior bar is shorter and bears at least two denticles that are similar to those found on the anterior bar. The apical denticle is large, laterally compressed anteriorly, and buttressed at its base on the inner side. The rounded buttress flares downward to connect the anterior and posterior limbs. A thin flat aboral extension is located at the base of the apical denticle on the outer side. The unit is moderately excavated beneath the apical denticle.

Remarks.—All specimens recovered were incomplete and abraded. The downward extension of the apical denticle on its outer side was not mentioned in Stauffer's original description of this species. This species also occurs in the upper Glenwood beds (Middle Ordovician) of Minnesota.

Repository.—Figured hypotype, S.U.I. 10119.

Genus GYROGNATHUS Stauffer, 1935
Type species: *G. primus* Stauffer, 1935
GYROGNATHUS ELONGATA Rhodes
Pl. 32, fig. 9

Gyrognathus elongatus RHODES, 1953, Royal Soc. London, Phil. Trans., s.B, no. 647, v. 237, p. 318,319, pl. 22, figs. 201,202,205,206.

Remarks.—The distal portion of the posterior bar of the figured specimen is missing. The cusp is identical in character to the denticles but slightly larger in size. Due to its small size and fragile nature, it seems probable that the figured specimen is not mature. In England, this species occurs in the Llandeilo Limestone which is Middle Ordovician in age.

Occurrence.—The figured specimen was collected from upper Bighorn limestone which crops out on the South Fork of Rock Creek, Johnson County, Wyoming.

Repository.—Figured hypotype, S.U.I. 10120.

Genus KEISLOGNATHUS Rhodes, 1955
Type species: *Keislognathus gracilis* Rhodes
KEISLOGNATHUS sp.
Pl. 32, fig. 6

Remarks.—The figured specimen is not sufficiently complete for positive identification. A posterior bar bearing "hindeodellid" denticulation is present and complete; the terminal fang is broken near its base. The abraded stub of aborally and posteriorly directed bar is found on the outer side of the fang. The rough and broken condition of the inner surface at the base of the fang indicates the probable existence of a lateral bar before abrasion took place. Cumulatively the specimen's characteristics make reference to *Keislognathus* a strong probability.

Occurrence.—The figured specimen was found at the locality on the South Fork of Rock Creek, Johnson County, Wyoming.

Repository.—Figured specimen, S.U.I. 10121.

Genus LONCHODUS Pander, 1856
Type species: *Centrodus simplex* Pander, 1856
LONCHODUS SPINULIFERUS Stauffer
Pl. 31, fig. 10

Lonchodus spinuliferus STAUFFER, 1932, Jour. Paleontology, v. 6, p. 258,263, pl. 40, fig. 32; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 126,127; SWEET, 1955, Jour. Paleontology, v. 29, p. 259, pl. 28, fig. 18.

Remarks.—The figured specimen is broken at both the posterior and anterior ends. The denticles are inclined posteriorly, laterally compressed, sharp edged, and taper orally to a sharp point. They are separated basally by a distance approximately equal to the width of one tooth. The basal bar is as wide as the basal portion of the denticles, is grooved aborally, and is sharp orally. In discussing the genus *Lonchodus*, Ulrich & Bassler (1926, p. 42) noted that this genus is based upon incomplete remains of teeth that may represent several genera. Sweet (1955, p. 259) emphasized that lonchodids

represent a distinct generic group as "indicated by the absence of forms referable to other genera which, even in fragmental form, bear any resemblance to typical specimens of *Lonchodus*." This species has been reported in Iowa, Kansas, Minnesota, and Colorado from Middle Ordovician strata.

Repository.—Figured hypotype, S.U.I. 10122.

Genus MICROCOELODUS Branson & Mehl, 1933
Type species: *M. typus* Branson & Mehl, 1933
MICROCOELODUS SWEETI Stone & Furnish, n.sp.
Pl. 31, fig. 18

Complex, asymmetrical dental units composed of an apical denticle on posterior and anterior denticulate bars. Apical denticle is long, slender, strongly recurved near its base, antero-posteriorly compressed, and oval in cross section. The base of this denticle extends laterally outward and posteriorly from the plane of the denticles on the bars. A carina extends upward from the base of the apical denticle on the inner side. The anterior bar makes an angle of 80°–90° with the posterior bar in the oral-aboral plane. The base of the anterior bar is laterally expanded near the apical denticle, is aborally excavated throughout, and is set with approximately four laterally compressed, recurved, sharp edged denticles. The posterior bar is flexed laterally toward the outer side, decreases in depth at its posterior end, and its base becomes flared anteriorly where it unites with the flared base of the apical denticle. It is set with five laterally compressed keeled denticles that do not all lie in the same plane. A deep basal cavity lies beneath the apical denticle.

Remarks.—This species is similar to *Microcoelodus symetricus* Branson & Mehl, 1933 but lacks the degree of symmetry.

Repository.—Figured holotype, S.U.I. 10123; unfigured paratypes, S.U.I. 10124.

Genus OISTODUS Pander, 1856
Type species: *O. lanceolatus* Pander, 1856
OISTODUS EXCELSUS Stauffer
Pl. 31, fig. 5

Oistodus excelsus STAUFFER, 1935b, Jour. Paleontology, v. 9, p. 610, pl. 74, fig. 43; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 135; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 725,726, pl. 86, figs. 4,7.

Remarks.—This is a common species of the upper Bighorn fauna. The specimens are usually abraded and broken at their bases and along anterior edges. In some specimens the amount of basal flaring is unequal. The cusp is inclined approximately 30° to the base and, in many cases, flexed laterally near the tip. This species has been identified from the Decorah Shale in Minnesota and Iowa and from the Elgin and Clermont members of the Maquoketa Formation in Iowa.

Repository.—Figured hypotype, S.U.I. 10127; unfigured specimens, 10128.

OISTODUS INCLINATUS Branson & Mehl
Pl. 31, fig. 6

Oistodus inclinatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 110, pl. 9, fig. 8; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 8, p. 135; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 726, pl. 86, fig. 11.

Remarks.—The anterior and posterior margins of the cusp in the figured specimen have been abraded. Most specimens show a tendency for the cusp to be flexed laterally and slightly twisted about its long axis. This species has been reported from formations ranging in age from Lower to Upper Ordovician.

Repository.—Figured hypotype, S.U.I. 10125; unfigured specimens, S.U.I. 10126.

Genus OULODUS Branson & Mehl, 1933
Type species: *O. mediocris* Branson & Mehl, 1933
OULODUS MEDIOCRIS Branson & Mehl
Pl. 32, figs. 4,5

Oulodus mediocris BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 116, pl. 10, figs. 8,9; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 136.

Complex dental units consisting of anterior and posterior denticulate bars and an apical denticle. Both bars join the apical denticle at its base; the anterior bar unites on the inner side and the posterior bar joins on the outer. In plan view the bars are not parallel; the posterior bar is directed laterally toward the outer side. The anterior bar is directed downward at an angle of approximately 90° from the posterior bar.

The anterior bar is slightly arched, moderately deep, and aborally excavated throughout. Its oral margin is set with approximately seven stout confluent posteriorly inclined denticles. The posterior bar is deeper than the anterior bar, and its oral margin is set with approximately four laterally compressed, posteriorly inclined denticles. The apical denticle is large, straight, and posteriorly inclined. Its base is oval in cross-section, the long axis being directed at an angle to the bar directions. Carinae extend upward from the junctions of the bars and the apical denticle. A sheath extends downward from the outer aboral margins of the bars. The inner margin of the entire unit is flared outward near the aboral margin to form a narrow ridge.

Remarks.—The extremities of both bars, the minor denticles, and the apical denticle were broken in the Bighorn specimens. There are at least three minor denticles on the posterior bar and at least five on the anterior bar. *Oulodus mediocris* also occurs in the Plattin Limestone of Missouri.

Repository.—Figured hypotype, S.U.I. 10131; unfigured specimens, S.U.I. 10132.

Genus OZARKODINA Branson & Mehl, 1933
Type species: *O. typica* Branson & Mehl, 1933

OZARKODINA? DELECTA Stauffer
Pl. 32, figs. 1,2

Ozarkodina delecta STAUFFER, 1935, Jour. Paleontology, v. 9, p. 148,159, pl. 10, fig. 40; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 137; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 735, pl. 88, figs. 8,9.

Remarks.—The anterior bar is almost twice as deep as the posterior bar, and both are excavated aborally. The posteriormost denticle and the cusp are intact in one specimen and illustrate their long sharp-pointed laterally compressed nature. Comparison of *O. delecta* with descriptions and illustrations of *O. typica* (Branson & Mehl, 1933), suggests that *O. delecta* is an atypical representative of the genus.

Occurrence.—*Ozarkodina delecta* occurs in Iowa, Minnesota, and Wyoming in Middle and Upper Ordovician strata. In Wyoming, it was found in upper Bighorn shales and limestones, in Johnson County.

Repository.—Figured specimens, S.U.I. 10133; unfigured specimens, S.U.I. 10134.

Genus PANDERODUS Ethington, 1959
Type species: *Paltodus unicostatus* Branson & Mehl, 1933

PANDERODUS FEULNERI (Glenister)
Pl. 31, fig. 3

Paltodus feulneri GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, fig. 11.

Remarks.—After examining the holotype and paratypes of this species, the authors are of the opinion that Glenister's description is incomplete. The median inner lateral carina becomes indistinguishable at about two thirds the cusp length, but the groove immediately posterior to the carina continues as an offset costa to the tip of the cusp where it is joined by the anterior offset carina. The outer side is marked by a fine carina which is medial in position, and extends from the base to the tip of the cusp. Specimens tend to be rather large and robust.

Repository.—Figured hypotype, S.U.I. 10135; unfigured specimens, S.U.I. 10136.

PANDERODUS GRACILIS (Branson & Mehl)
Pl. 31, fig. 2

Paltodus gracilis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 108, pl. 8, figs. 20,21; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, figs. 2–5.

Remarks.—This species is abundant in the upper Bighorn. A considerable variation in size and curvature is shown. *Panderodus gracilis* has been recovered from formations ranging in age from Middle to Upper Ordovician.

Repository.—Figured hypotype, S.U.I. 10141; unfigured specimens, S.U.I. 10142.

PANDERODUS INTERMEDIUS (Branson, Mehl & Branson)
Pl. 31, fig. 1

Paltodus intermedius BRANSON, MEHL & BRANSON, 1951, Jour. Paleontology, v. 25, p. 7, pl. 1, figs. 9–15; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, fig. 10.

Remarks.—The upper Bighorn specimens are closely similar to the type material. In Iowa, this species occurs in the Maquoketa Formation, and in Indiana and Kentucky it is found in the upper parts of the Richmond Group.

Repository.—Figured hypotype, S.U.I. 10139; unfigured specimens, S.U.I. 10140.

PANDERODUS PANDERI (Stauffer)
Pl. 31, fig. 4

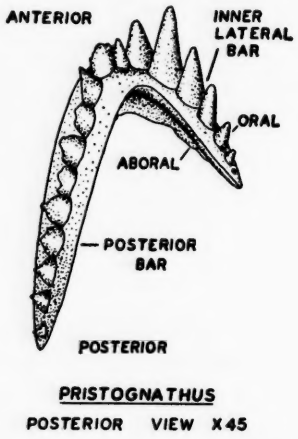
Paltodus panderi STAUFFER, 1940, Jour. Paleontology, v. 14, p. 427, pl. 60, figs. 8,9; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 144; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728,729, pl. 85, figs. 8,9.

Remarks.—This species is not common in the upper Bighorn fauna. The specimens that were collected are closely similar to the type material. The species was originally described by Stauffer from residual clay deposits that contain both Devonian and Ordovician conodonts. He concluded that *P. panderi* was a member of the Ordovician admixture. This species also occurs in the Maquoketa Formation of Iowa and Minnesota.

Repository.—Figured hypotype, S.U.I. 10137; unfigured specimens, S.U.I. 10138.

Genus PRISTOGNATHUS Stone & Furnish, n. gen.
Type species: *P. bighornensis* Stone & Furnish

Compound dental units consisting of a laterally expanded aborally excavated hook-shaped denticulate bar. Relatively short, discrete, laterally compressed denticles become progressively larger anteriorly, but a cusp is not present. The aboral excavation is narrow through most of its length and is enlarged at the bend of the hook.



TEXT-FIG. 1—Orientation and terminology of new genus.

Orientation.—Apex of the lateral bend is regarded as anterior. The bar is divided into two segments by the lateral bend. The longer segment is designated as the posterior bar and the shorter segment as the inner lateral bar.

Remarks.—This genus is somewhat similar to both *Oulodus* Branson & Mehl, and *Gyrognathus* Stauffer. Ellison (1946) suggested that *Gyrognathus* is a junior synonym of *Oulodus*. Rhodes (1953) discussed this problem and recommended that *Gyrognathus* be retained to include forms resembling *Oulodus*, in which the aboral surface is not laterally expanded but is thin and blade-like. The genus here described differs from *Oulodus* and *Gyrognathus* in that it does not possess a cusp. It further differs from *Gyrognathus* in that the bar is laterally expanded. In addition to a common occurrence in the upper Bighorn, the genus has been observed in the Stony Mountain Formation of southern Manitoba.

PRISTOGNATHUS BIGHORNENSIS
Stone & Furnish, n. sp.
Pl. 32, figs. 7,8

A relatively long, laterally expanded, aborally excavated, denticulate, hook-shaped bar. The bend of the hook divides the bar into a lateral portion and a posterior portion. The posterior segment curves sharply downward in the oral-aboral plane near the anterior end. The lateral bar is nearly straight but it is slightly twisted about its long axis. Both segments are aborally excavated by a narrow shallow groove which is expanded and deepened in the vicinity of the lateral bend. Distal portions of the bars taper to a point. Bar segments are somewhat rounded aborally and flattened orally. The oral surface is set with a median row of approximately nineteen short laterally compressed, discrete, blade-like denticles. Denticles are shortest at the extremities of the segments and become progressively longer anteriorly and are of maximum size at the lateral bend.

Remarks.—This is a very common species in the Bighorn fauna. Most of the specimens were broken at the lateral bend, and the extremities of the lateral segment are seldom preserved. A closely allied undescribed species has been observed in shale portion of the Stony Mountain Formation.

Repository.—Figured holotype, S.U.I. 10147; unfigured paratypes, S.U.I. 10148.

Genus TETRAPRIONIODUS Lindström, 1954
[=ROSAGNATHUS Rhodes, 1955]
Type species: *T. robustus* Lindström, 1954
TETRAPRIONIODUS SUPERBUS (Rhodes)
Pl. 32, fig. 13

Rosagnathus superbus RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 129,130,138, pl. 7, figs. 1–4.

Remarks.—The figured specimen is somewhat abraded but all elements are present. The oral portions of the lateral bars are absent. The anterior aboral process and the anterior denticle are anterior and outer-aboral in position with reference to the fang. A very small denticle is fused to the outer side of the anterior denticle. *Tetraprioniodus superbus* has been described from the Keisley Limestone of England and, in this study, from the upper Bighorn Formation of north-central Wyoming. The Keisley is considered to be Upper Ordovician in age (Rhodes, 1955).

Repository. Figured hypotype, S.U.I. 10149.

Genus TRICHONODELLA Branson & Mehl, 1948
Type species: *Trichognathus prima* Branson & Mehl, 1933
TRICHONODELLA BARBARA (Stauffer)
Pl. 32, fig. 15

Trichognathus barbarus STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 155,160, pl. 12, fig. 11; FURNISH, BARRAGY & MILLER, 1936, Am. Assoc. Petroleum Geologists, Bull., v. 20, p. 1334, pl. 1, fig. 1; STAUFFER & THIEL, 1941, Minn. Geol. Survey, Bull. 29, p. 245.
Trichonodella barbara FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 198.

Remarks.—One of the denticulate lateral bars is nearly complete and bears three slender, moderately recurved, carinate denticles. The denticulate posterior bar is set with a small node at the base of the apical denticle which is followed by a thin laterally compressed tooth, and a narrow ridge extends from the tooth to the posterior margin. Prior to this study, *T. barbara* has been described from the upper Glenwood beds of Minnesota and the lower Whitewood Formation of South Dakota.

Repository.—Figured hypotype, S.U.I. 10145.

TRICHONODELLA RECURVA
(Branson & Mehl)
Pl. 32, fig. 14

Trichognathus recurva BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 119, pl. 10, fig. 6; STAUFFER, 1935a, Geol, Soc. America, Bull., v. 46, p. 156,160, pl. 12, figs. 1,2; STAUFFER, 1935b, Jour. Paleontology, v. 9, p. 619–620, pl. 71, figs. 20,27,39,41,47, pl. 72, figs. 48,56, pl. 75, fig. 22; FURNISH, BARRAGY & MILLER, 1936, Am. Assoc. Petroleum Geologists, Bull., v. 20, p. 1334; BRANSON, 1944, Missouri Univ. Studies, v. 19, p. 82.
Trichonodella recurva FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 199; SWEET, 1955, Jour. Paleontology, v. 29, p. 258, pl. 29, figs. 1,2.

Remarks.—All the specimens studied were to some degree fragmentary. A few specimens show lateral denticles intact and indicate that this portion is gently recurved. The most nearly complete specimens have four denticles on each lateral bar. *Trichonodella recurva* has been identified in Missouri, Minnesota, Iowa, South Dakota, Colorado and Wyoming from Middle Ordovician strata.

Repository.—Figured hypotype, S.U.I. 10143; unfigured specimens, S.U.I. 10144.

REFERENCES

AMSDEN, T. W., & MILLER, A. K., 1942, Ordovician conodonts from the Bighorn Mountains of Wyoming: Jour. Paleontology, v. 16, p. 301–306, pl. 41.
BAILLIE, A. D., 1952, Ordovician geology of Lake Winnipeg and adjacent areas, Manitoba: Manitoba Dept. Mines & Nat. Res., Publ. 50-1, 81 p., 1 pl.
BLACKWELDER, ELIOT, 1918, New geological formation in western Wyoming: Washington Acad. Sci., Jour., v. 8, p. 417–426.
BRANSON, E. B., 1944, The geology of Missouri: Missouri Univ. Studies, v. 19, no. 3, 535 p.
—— & BRANSON, C. C., 1941, Geology of the Wind River Mountains: Am. Assoc. Petroleum Geologists Bull., v. 25, p. 120–151.
—— & MEHL, M. G., 1933, Conodont Studies: Missouri Univ. Studies, v. 8, 349 p., 28 pls.
——, —— & BRANSON, C. C., 1951, Richmond conodonts of Kentucky and Indiana: Jour. Paleontology, v. 25, p. 1–17, pls. 1–4.
BRYANT, W. L., 1936, A study of the oldest known vertebrates, *Astropis* and *Eriptychius:* Am. Phil. Soc. Proc., v. 76, p. 409–427, 13 pls.
DARTON, N. H., 1906a, Fish remains in Ordovician rocks in Bighorn Mountains, Wyoming, with a résumé of Ordovician geology of the Northwest: Geol. Soc. America, Bull., v. 17, p. 541–556.
——, 1906b, Description of the Bald Mountain and Dayton quadrangles, Wyoming: U. S. Geol. Atlas, folio 141, 15 p.

——, 1906c, Description of Cloud Peak and Fort McKinney quadrangles, Wyoming: U. S. Geol. Atlas, folio 142, 16 p.

——, 1906d, Geology of the Bighorn Mountains: U. S. Geol. Survey, Prof. Paper 51, 129 p.

DUNCAN, H. M., 1956, Ordovician and Silurian coral faunas of Western United States: U. S. Geol. Survey, Bull. 1021-F, p. 167–193, pls. 21–27.

——, 1957, *Bighornia*, a new Ordovician coral genus: Jour. Paleontology, v. 31, p. 604–615, pl. 70.

ELLISON, S. P., 1946, Conodonts as Paleozoic guide fossils: Am. Assoc. Petroleum Geologists, Bull., v. 30, p. 93–110.

ETHINGTON, R. L., 1959, Conodonts of the Ordovician Galena Formation: Jour. Paleontology, v. 33, p. 257–292, pls. 39–41.

FAY, R. O., 1952, Catalogue of conodonts: Univ. Kansas Paleontological Contributions, Vertebrata, Article 3, 206 p.

FLOWER, R. H., 1957, Studies of the Actinoceratida: New Mexico Inst. Min. & Tech., Memoir 2, 100 p., 13 pls.

——, 1958, Some Chazyan and Mohawkian Endoceratida: Jour. Paleontology, v. 32, p. 433–458, pls. 59–62.

FOERSTE, A. F., 1935, Bighorn and related cephalopods: Denison Univ. Bull., Jour. Sci. Labs., v. 30, 196 p., 22 pls.

FURNISH, W. M., BARRAGY, E. J., & MILLER, A. K., 1936, Ordovican fossils from upper part of type section of Deadwood Formation, South Dakota: Am. Assoc. Petroleum Geologists, Bull., v. 20, p. 1329–1341, pls. 1,2.

GLENISTER, A. T., 1957, The Conodonts of the Ordovician Maquoketa Formation in Iowa: Jour. Paleontology, v. 31, p. 715–736, pls. 85–88.

GRAVES, R. W., & ELLISON, S. P., 1941, Ordovician conodonts of the Marathon Basin, Texas: Missouri Univ. School Mines & Metall., Bull., Tech. Ser., v. 14, no. 2, 36 p., 3 pls.

HOLLAND, F. D. & WALDREN, C. H., 1955, Conodonts in the Winnipeg Formation (Ordovician) of North Dakota [abstract]: Geol. Soc. America, Bull., v. 66, p. 1574.

HOSE, R. K., 1955, Geology of the Crazy Woman Creek area, Johnson County, Wyoming: U. S. Geol. Survey, Bull. 1027-B, p. 33–118.

IMBT, W. C., 1941, Zenith pool, Stafford County, Kansas, an example of stratigraphic trap accumulation, *in* Stratigraphic type oil fields: Am. Assoc. Petroleum Geologists, Spec. Publ., A. I. Levorson, ed., p. 139–165.

KAY, G. N., 1935, Ordovician Stewartville-Dubuque problems: Jour. Geology, v. 43, p. 561–590.

KIRK, EDWIN, 1925, Notes on an early collection of Paleozoic fossils from Ellesmereland, Am. Jour. Sci., 5th Ser., v. 10, p. 445–447.

——, 1930, The Harding Sandstone of Colorado: Am. Jour. Sci., 5th ser., v. 19, p. 456–466.

LINDSTRÖM, MAURITS, 1954, Conodonts from the lowermost Ordovician strata of south-central Sweden: Geol. Fören. Stockholm, Förhandl., Bd. 76, H. 4, p. 517–604, pls. 2–10.

MILLER, A. K., 1930, The age and correlation of the Bighorn Formation of northwestern United States: Am. Jour. Sci., 5th Ser., v. 20, p. 195–213.

——, 1932, The cephalopods of the Bighorn Formation of the Wind River Mountains of Wyoming: Connecticut Acad. Arts Sci., Trans., 297 p., 30 pls.

—— & FURNISH, W. M., 1937, Ordovician cephalopods from the Black Hills, South Dakota: Jour. Paleontology, v. 11, p. 535–551, pls. 66–69.

—— et al., 1954, Ordovician cephalopods of Baffin Island: Geol. Soc. America, Mem. 62, 234 p., 63 pls.

ØRVIG, TOR, 1958, *Pycnaspis splendens*, new genus, new species, a new ostracoderm from the Upper Ordovician of North America: U. S. Nat. Mus., Proc., v. 108, no. 3391, p. 1–23, pls. 1–3.

RHODES, F. H. T., 1953, Some British Lower Palaeozoic conodont faunas: Royal Soc. London, Phil. Trans., ser. B., no. 647, v. 237, p. 261–337, pls. 30–33.

——, 1955, The conodont fauna of the Keisley Limestone: Geol. Soc. London, Quart. Jour., v. 111, p. 117–142, pls. 7–10.

RICHARDS, P. W. & NIESCHMIDT, C. L., 1957, Bighorn Dolomite in south-central Montana and northwestern Wyoming: Billings Geol. Soc. Guidebook, Eighth Annual Field Conference, p. 54–62.

ROSS, R. J., 1957, Ordovician fossils from wells in the Williston Basin eastern Montana: U. S. Geol. Survey, Bull. 1021-M, p. 439–506, pls. 37–43.

STAUFFER, C. R., 1932, Decorah Shale conodonts from Kansas: Jour. Paleontology, v. 6, p. 257–264, pl. 40.

——, 1935a, Conodonts of the Glenwood beds: Geol. Soc. America, Bull., v. 46, p. 125–168, pls. 9–12.

——, 1935b, The conodont fauna of the Decorah Shale (Ordovician): Jour. Paleontology, v. 9, p. 596–620, pls. 71–75.

SWEET, W. C., 1954, Harding and Fremont Formations, Colorado: Amer. Assoc. Petroleum Geologists, Bull., v. 38, p. 284–305.

——, 1955, Conodonts from the Harding Formation (Middle Ordovician) of Colorado: Jour. Paleontology, v. 29, p. 226–262, pls. 27–29.

TOMLINSON, C. W., 1917, The middle Paleozoic stratigraphy of the central Rocky Mountain Regon: Jour. Geology, v. 25, p. 112–134,244–257,373–394.

TWENHOFEL, W. H., et al., 1954, Correlation of the Ordovician formations of North America: Geol. Soc. America, Bull., v. 65, p. 247–298, pl. 1.

WANLESS, H. R., et al., 1955, Paleozoic and Mesozoic rocks of Gros Ventre, Teton, Hoback, and Snake River ranges, Wyoming: Geol. Soc. America, Mem. 63, 90 p., 13 pls.

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ARENACEOUS FORAMINIFERA FROM THE ROCKFORD LIMESTONE OF NORTHERN INDIANA

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ABSTRACT—Several thousand arenaceous Foraminifera have been obtained from insoluble residues of Mississippian Kinderhook Rockford limestone collected from two localities in Jasper and Benton Counties, Indiana. Fourteen or more genera and 33 species, 22 of which are new, represent the families Astrorhizidae, Saccamminidae, Hyperamminidae, Reophacidae, Tolypamminidae (includes ammodiscids), and Lituolidae. Distribution of forms is divided between those with affinities to older Silurian and Devonian faunas, and others, in greater number, with affinities to the younger Pennsylvanian arenaceous Foraminifera. No other systematic studies of arenaceous Foraminifera are available of Kinderhook faunas of the United States on which to base a paleontologic comparison.

INTRODUCTION

PUBLISHED information on Lower Mississippian Foraminifera in North America has been lacking and yet there is a widespread diverse fauna present in these beds. Insoluble residues of Lower Mississippian Kinderhook Rockford limestone from two localities in northern Indiana have yielded many thousands of specimens of arenaceous Foraminifera. From these samples 14 genera (possibly two others) and 33 species, of which 22 are new, have been identified. They are in the families Astrorhizidae, Saccamminidae, Hyperamminidae, Reophacidae, Tolypamminidae (including ammodiscids), and Lituolidae.

We want to thank Dr. William Wayne of the Indiana Geological Survey for calling our attention to the locality south of Remington, Indiana, and to Mr. James Conkin of the University of Louisville for furnishing us with specimens of *Hyperammina kentuckyensis* Conkin from the Mississippian Floyds Knob formation of Kentucky. Dr. Charles Summerson of Ohio State University kindly furnished us with an unpublished manuscript of his paper on arenaceous Foraminifera from the Middle Devonian Columbus limestone of Ohio.

LOCALITIES

The rock samples from which the fossils were obtained come from the following two places:

1. Exposed section adjacent to an abandoned small shallow water-filled quarry in Mr. Chris E. Alter's farmyard along the head of Meadel Ditch (county highway map) near the center of the NW$\frac{1}{4}$, sec. 21, T. 27 N., R. 7 W., Jasper County, Indiana, which is about 3$\frac{1}{2}$ miles WNW. of Remington. Shrock & Malott (1929) call attention to the Rockford exposure found here. Gutschick & Treckman (1957) diagram this section.
2. Limestone spoil bank along Carpenter Creek in center of N$\frac{1}{2}$ of the NE$\frac{1}{4}$, sec. 1. T. 26 N., R. 7 W., Benton County, Indiana, which is about 2 miles south of Remington. The rock has been blasted out along Carpenter Creek to deepen ditch. There is little or no rock cropping out here but quite a large amount found loose piled up along the east side of the ditch. It is not possible to determine the stratigraphic sequence nor rock unit thickness; however it compares very closely with locality 1 in lithology and fauna.

PREVIOUS WORK

There have been no systematic published studies of Kinderhook arenaceous Foraminifera, or for that matter for the entire Mississippian, and yet the fauna described in this paper has been found, at least in large part, in the Mississippi Valley, the midcontinent region of Oklahoma and Texas, and the Rocky Mountains. The fauna(s) have not been unknown. Several references have been made to such occurrences and in a few cases, the genera have been listed. The Mis-

sissippian calcareous Foraminifera have received some attention but no summary is attempted here. C. L. Cooper (1947; 1948) indicates a few of the Kinderhook formations which contain Foraminifera and lists some genera. Conkin (1954; 1957) describes an Osage hyperamminid and outlines the stratigraphic paleontology of the smaller Foraminifera in east-central United States. Workman & Gillette (1956) list genera for the Louisiana, McCraney, and Chouteau formations of Illinois.

MORPHOLOGY AND ACID RESIDUES

Through the recent studies of Wood (1949) and Cummings (1955) much emphasis has been placed on details of wall structure. Cummings (1955) points out the inadequacy of the hydrochloric acid test as applied to the study of Paleozoic microfaunas.

It is true that acid residues reveal the insoluble characteristics whether they be original or replacement phenomena for the fossils, and that soluble test materials are lost through solution. Another fact is that all calcareous tests and those which employ lime as a cement will be lost unless they are replaced by siliceous or other insoluble materials. This may eliminate a very important element of the fauna and lend some artificiality to the concentrates of recovered arenaceous forms. This can be overcome to some degree by examining water washed samples from interbedded shales for comparison such as Ireland's (1956) work with Pennsylvanian forms. The Rockford section at the Alter's locality 1 has shale partings in the Rockford which yields Foraminifera in water washed samples although the shales suffer from normal diagenetic changes including compaction. It is interesting to note that no forms other than those present in the acid residues were observed in the shales. One other method of extracting the Foraminifera without seriously altering their composition is through the use of thin-sections and petrographic analysis. This is discussed in Cumming's article (1958).

DISCUSSION OF FAUNA

The following is a list of the arenaceous Foraminifera recognized in the Rockford limestone of northern Indiana:

Astrorhiza? sp.
Pseudastrorhiza delicata, n. sp.
Psammosphaera cava Moreman
Sorosphaera papilla, n. sp.
Lagenammina sphaerica Moreman
Thurammina diforamens Ireland
Thurammina furcata, n. sp.
Thurammina limbata Dunn
Thurammina quadritubulata Dunn
Thurammina triradiata, n. sp.
Thuramminoides? sp.
Hyperammina bulbosa Cushman & Waters
Hyperammina compacta, n. sp.
Hyperammina constricta, n. sp.
Hyperammina gracilenta, n. sp.
Hyperammina nitida, n. sp.
Hyperammina rockfordensis, n. sp.
Hyperammina? sp.
Reophax buccina, n. sp.
Reophax lachrymosa, n. sp.
Reophax? sp.
Involutina exsertus (Cushman)
Involutina longexsertus, n. sp.
Involutina semiconstrictus (Waters)
Ammodiscella virgilensis Ireland
Glomospira articulosa Plummer
Tolypammina botonuncus, n. sp.
Tolypammina cyclops, n. sp.
Tolypammina extenda Ireland
Tolypammina rotula, n. sp.
Tolypammina sp. A
Tolypammina sp. B.
Ammovertella bulbosa, n. sp.
Trepeilopsis glomospiroides, n. sp.
Trepeilopsis prodigalis, n. sp.
Trepeilopsis recurvidens, n. sp.
Trepeilopsis spiralis, n. sp.
Ammobaculites leptos, n. sp.
Ammobaculites pyriformis, n. sp.
Ammobaculites? sp.

The order in which the families of Foraminifera appear in numbers and diversity is: very common to abundant—tolypamminids, hyperamminids, saccamminids; common—reophacids, lituolids; uncommon—astrorhizids. There is nothing in the literature of the United States on which to base any comparison for Mississippian Foraminifera. There are quite a few forms which at the present time are unique to the Rockford. The saccamminids and astrorhizids seem to be more closely related to those in older formations, whereas the tolypamminids, hyperamminids, reophacids, and lituolids are largely forerunners to late Paleozoic faunas. It is interesting to note that no biserial forms are present in the Rockford.

ECOLOGY

Rockford lithology consists of yellow-grey fine-grained argillaceous crinoidal limestone with small black rounded phosphatic

pebbles in its basal part. There are also 1 to 2 inch interbeds of calcareous fossiliferous shale. The HCl acid residues are largely made up of fine silty granular siliceous porous aggregates, undoubtedly argillaceous, and arenaceous Foraminifera in abundance. There are some quartz sand grains, silicified fragmental fossil material, pyrite, rare glauconite, and occasional radial aggregates of fine needle-like crystals of millerite.

The megafossils of the Rockford include the nautiloid and goniatite cephalopods *Aipoceras?* sp., *Mooreoceras* spp., *Posterioceras?* sp., *Welleroceras liratum*, *Gattendorfia alteri*, and *Prodromites gorbyi* (Gutschick & Treckman, 1957), which apparently came from the shale partings. Other large fossils are scarce because of limited exposures, but include both large and diminutive forms of brachiopods, corals, bryozoans, gastropods, trilobites, abundant echinoderm debris, and fish fragments.

The microfaunas include conodonts, holothurian sclerites, microcrinoids, ostracodes, worm tubes, and other material. Most, if not all, are calcareous or phosphatic and are found in the water washings of the calcareous shale interbeds.

Ireland (1956) has faunas from cyclical Pennsylvanian sediments to deal with and consequently more ecologic control. He found that the arenaceous Foraminifera prefer the shallow water environment of the regressive sea and occur in abundance in the algal limestones. He also found them associated with fusulinids, indicating broad tolerance for deeper water of the maximum transgressive phase. Comparing the gross aspects of the fauna, the Rockford has much in common with the Pennsylvanian Foraminifera described by Ireland, except for the lack of algal limestone association in the former.

Said (1953) studied the distribution of Foraminifera in a tidal embayment along the Massachusetts coast and found arenaceous Foraminifera living in the area of lowest salinity. The major portion of the fauna of the Rockford is diminutive which suggests some restrictions in general normal marine conditions.

CONCLUSIONS

The Rockford limestone and Chouteau correlatives have a rich and varied fauna, including abundant arenaceous Foraminifera. Documentation of arenaceous Foraminifera of the Paleozoic in the United States is in the beginning stage. The early Mississippian arenaceous Foraminifera show great promise of being very useful for correlation, phylogeny, and ecology.

While the acid residue method has inherent limitations, there is much to defend its use. Realization of the number and diversity of such fauna would be impossible by any other currently known method. Limited study of Rockford limestone thin-sections has failed to reveal the fauna in spite of its abundance in the residues.

This fauna demonstrates that the arenaceous Foraminifera of the Lower Mississippian is diverse and abundant. It should encourage greater search to fill in the broad gaps in the Paleozoic foraminiferal record. Although this is a faunal study, there is good indication that a study of the phylogeny of the hyperamminids and tolypamminids will greatly aid in the stratigraphic paleontology of the Lower Mississippian. The fauna has a number of unique forms which may be diagnostic for the Rockford. It contains the oldest record of the genus *Ammobaculites* and has not yielded any biserial forms.

Rockford Foraminifera type specimens of this report will be deposited in the U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA

Family ASTRORHIZIDAE Cushman, 1925

Genus ASTRORHIZA Sandahl, 1858

ASTRORHIZA? sp.

Pl. 33, figs. 23,24

The test is small, globular, compressed, and has six or more conical tubular projections arranged in a plane around its equatorial diameter. The thin wall is composed of silt to fine sand, fairly well cemented with moderately rough granular surface. Apertures are on ends of the projections. The greatest diameter of the adult test is 0.28 mm.; projections are approximately 0.05 mm. long. This single specimen may be a variant of *Thurammina*.

Genus PSEUDASTRORHIZA Eisenack, 1932

PSEUDASTRORHIZA DELICATA Gutschick & Treckman, n. sp.

Pl. 33, figs. 1–5

The test is free, consisting of a central chamber from which tubular projections radiate outward. Central part of test is irregularly subglobular. Arrangement of projections irregular in position in various planes, number of projections vary from nine to twelve on complete specimens, simple, slender tapering tubules. The thin fragile wall is composed of fairly well cemented, very fine sand to coarse silt-size quartz grains. Apertures are not apparent. Specimens are white in color.

Measurements of the holotype and a single paratype are given below. The types were chosen from among more than 15 fragmentary to complete specimens in the collection.

	Pl. 33, fig. 3 Holotype	Pl. 33, figs. 1,2 Paratype
Maximum diameter	0.55 mm.	0.53 mm.
Length of projections	0.16–0.20 mm.	0.18 mm.
Diameter of central part	0.25 mm.	0.24 mm.
Number of radiating tubules	12	11
Diameter of tubules at their base	0.09 mm.	0.07 mm.
Minimum diameter of tubes	0.04–0.05 mm.	0.04 mm.

Remarks.—Of the described forms, this species resembles *Pseudastrorhiza irregularis* Dunn (1942) but differs from it in having tubules which are narrower at their base, are more discrete from the central part, are more slender cylindrical finger-like projections, and are greater in number. The species is present in both localities but is common in the Remington section and rare in the Alter's section.

Family SACCAMMINIDAE Cushman, 1927
Subfamily PSAMMOSPHAERINAE Cushman, 1927
Genus PSAMMOSPHAERA Schulze, 1875
PSAMMOSPHAERA CAVA Moreman
Pl. 33, figs. 6,7

Psammosphaera cava MOREMAN, 1930, Jour. Paleontology, v. 4, p. 48, pl. 6, fig. 12.

"Test free, spherical; wall thin, composed mostly of fine sand grains, well cemented; aperture indefinite; color white."

The holotype comes from the Lower Silurian Chimney Hill limestone of the Arbuckle Mountains, Oklahoma.

The diameter of the large figured specimen is 0.56 mm. That of the smaller specimen is 0.36 mm.

Remarks.—Many specimens were found which are almost exact duplicates of the Silurian species described by Moreman. Simple spherical forms like *Psammosphaera* are difficult to separate into species. Careful study of Ordovician forms of this genus indicates that the test is susceptible to deformation by crushing into innumerable shapes which occur again and again. There seems to be insignificant phylogenetic difference throughout the Paleozoic for this simple genus.

Occurrence.—This species is common in both localities.

Genus SOROSPHAERA H. B. Brady, 1879
SOROSPHAERA PAPILLA Gutschick & Treckman, n. sp.
Pl. 33, figs. 8–13

The test is free and multichambered, composed of a cluster of two or more spherical to ellipsoidal chambers irregularly arranged, not necessarily in one plane. Chambers are joined firmly to loosely. They are thuramminoid in the sense that individually they resemble the genus *Thurammina* with simple, non-labyrinthic, globular shape and scattered short protuberances which have suggestions of apertures on their extensions. The thin test wall, which has an irregular outer surface, is composed of fine subangular loosely cemented sand. The color of the holotype is grayish-orange.

Eight specimens which include figures 8,10–13 on Plate 33 have chambers with average diameter, 0.24 mm. and vary in number from two to six. The holotype has five chambers. Two specimens as illustrated by figure 9, Plate 33, have chambers with average diameter of, 0.13 mm. and vary in number from four to eleven. The maximum diameter of the holotype is 0.66 mm.

Remarks.—While there seems to be quite a variation in size, shape, number, and arrangement of chambers, the species is characterized by the thuramminoid chambers with projections and the tendency to be loosely packed. Grubbs (1939) expresses

our feelings when he says that several species erected on the number of chambers may be due to separation of the chambers from composite individuals. Such polythalmous forms can easily be broken apart thereby forming mono-, bi-, tri-, etc. loculus forms; therefore it seems superfluous to attempt to split this form into several species based upon material in the collection.

Genus LAGENAMMINA Rhumbler, 1911
LAGENAMMINA SPHAERICA Moreman
Pl. 33, fig. 14

Lagenammina sphaerica MOREMAN, 1930, Jour. Paleontology, v. 4, p. 51, pl. 5, fig. 15.

"Test free, small, bottle-shaped, that part of the chamber below the neck almost perfectly spherical, neck about two-fifths the length of the entire test; wall thin, composed of medium sand, surface rough; aperture circular at the end of an elongate neck; color white."

The holotype comes from the Lower Silurian Chimney Hill limestone from north of Bromide, Arbuckle Mountains, Oklahoma.

The length of the figured specimen is 0.40 mm. and its diameter is 0.26 mm.

Remarks.—One specimen was found, and its form is an almost duplicate of the Silurian species described by Moreman. The neck is very fragile which may account for its rarity as differentiate from *Psammosphaera.*

Occurrence.—Alter's section

Genus THURAMMINA Rhumbler, 1911
THURAMMINA DIFORAMENS Ireland
Pl. 33, fig. 15

Thurammina diforamens IRELAND, 1956, Jour. Paleontology, v. 30, p. 841, fig. 3–6,7.

"Test free, highly inflated, spherical, two neck-like projections on opposite sides low down below center of the sphere; wall thin, fragile, with uniform size fine quartz particles well cemented; aperture on end of each projection."

Specimens come from the Upper Pennsylvanian Virgil series in Kansas.

The diameter of the Rockford figured specimen, Plate 33, figure 15, is 0.39 mm. for the spherical chamber and 0.16 mm. for the length of the projections. The length of the entire specimen is 0.65 mm.

Remarks.—This Mississippian form is larger than the Pennsylvanian material but otherwise agrees very well in shape.

Occurrence.—This species occurs in both localities.

THURAMMINA TRIRADIATA Gutschick & Treckman, n. sp.
Pl. 33, fig. 16,17

The test is free consisting of a fairly large simple spherical central chamber and three radiating tube-like projections arranged in one plane. The thin test wall is composed of fine well cemented sand grains and has a smooth surface. The tube-like projections have terminal apertures.

The diameter of the test from the end of one projection to the opposite side is 0.65 mm. The diameter of the central chamber is 0.40 mm. and the diameter of the projections is 0.05 mm. The thickness of the wall is 0.02–0.03 mm.

Remarks.—This form is similar to *Thurammina trituba* Dunn (1942) from the Middle Silurian Osgood limestone of Missouri but the central chamber is much larger and more spherical than the triangular Silurian form.

Occurrence.—This species occurs at both localities. The holotype is from the Alter's section.

THURAMMINA QUADRITUBULATA Dunn
Pl. 33, fig. 18

Thurammina quadritubulata Dunn, 1942, Jour. Paleontology, v. 16, p. 334, pl. 43, fig. 22.

"Test free, spherical, with four blunt tubular necks arranged in opposite pairs, the horizontal plane of one pair cutting the vertical plane of the other at right angles. Viewed from above, however, the four tubes do not lie in vertical planes through the center of the sphere but are offset on opposite sides of perpendicular vertical central planes. Wall thin, composed of medium-sized sand grains, well cemented, surface rough; apertures at ends of tubular necks."

The holotype is from the Middle Silurian Bainbridge limestone of Missouri.

The diameter of the figured Rockford specimen with its projections is 0.57 mm. The diameter of the central chamber is 0.45 mm.

Remarks.—This form is larger than the type specimen otherwise it is the same.

Occurrence.—Alter's locality.

THURAMMINA FURCATA Gutschick & Treckman, n. sp.
Pl. 33, figs. 19,20

The test is free and is composed of a cen-

tral simple spherical chamber with four or five tubular projections. One pair of tubules are highly divergent whereas the other pair lie close together and only slightly divergent. The two planes containing each pair of projections are not at right angles to each other but intersect close to the center of the test at an angle which varies from 30° to 70°. The length of the tubes are almost half of the diameter of the central chamber. The thin wall is composed of fine well cemented sand grains and has a smooth surface.

The maximum diameter of the test with its projections is 0.60 mm. The central chamber is 0.38 mm. in diameter and the length of the projections is 0.12 mm. They taper from 0.05 mm. at their base to 0.025 mm. at their distal extremities.

Remarks.—This species is characterized by the two closely forked projections which occur opposite two or three divergent projections.

Occurrence.—Specimens of this species occur at both localities. The holotype is from the Alter's section.

THURAMMINA LIMBATA Dunn
Pl. 33, fig. 22

Thurammina limbata DUNN, 1942, Jour. Paleontology, v. 16, p. 332, pl. 43, fig. 34.

"Test free, spherical or subspherical, with a row of prominent nipplelike projections around the periphery; wall thin, of medium to large sand grains, usually well cemented; surface rough; number of projections averages ten; aperture at ends of tubes."

The holotype is from the Middle Silurian Bainbridge limestone of Missouri.

The Rockford specimen has the same general form as *Thurammina limbata* Dunn. It contains nine or ten projections and is larger than the Silurian specimens. The diameter of the Rockford test with its projections is 0.70 mm. and 0.53 mm. without them.

Genus THURAMMINOIDES Plummer, 1945
THURAMMINOIDES? sp.
Pl. 33, fig. 25

One unique fragmentary well-preserved specimen was found which has been identified tentatively. Since only ½ to ⅔ of the original test is present, it does not seem wise to use this as the type for a new form; yet it is different than anything in the literature and should be described. The large globular test is covered with many nipple-like projections which are hollow inside. The thin fragile test wall is composed of fine sand grains only moderately cemented together. The outer surface is rough and the inner surface more so. The projections are inflated cones.

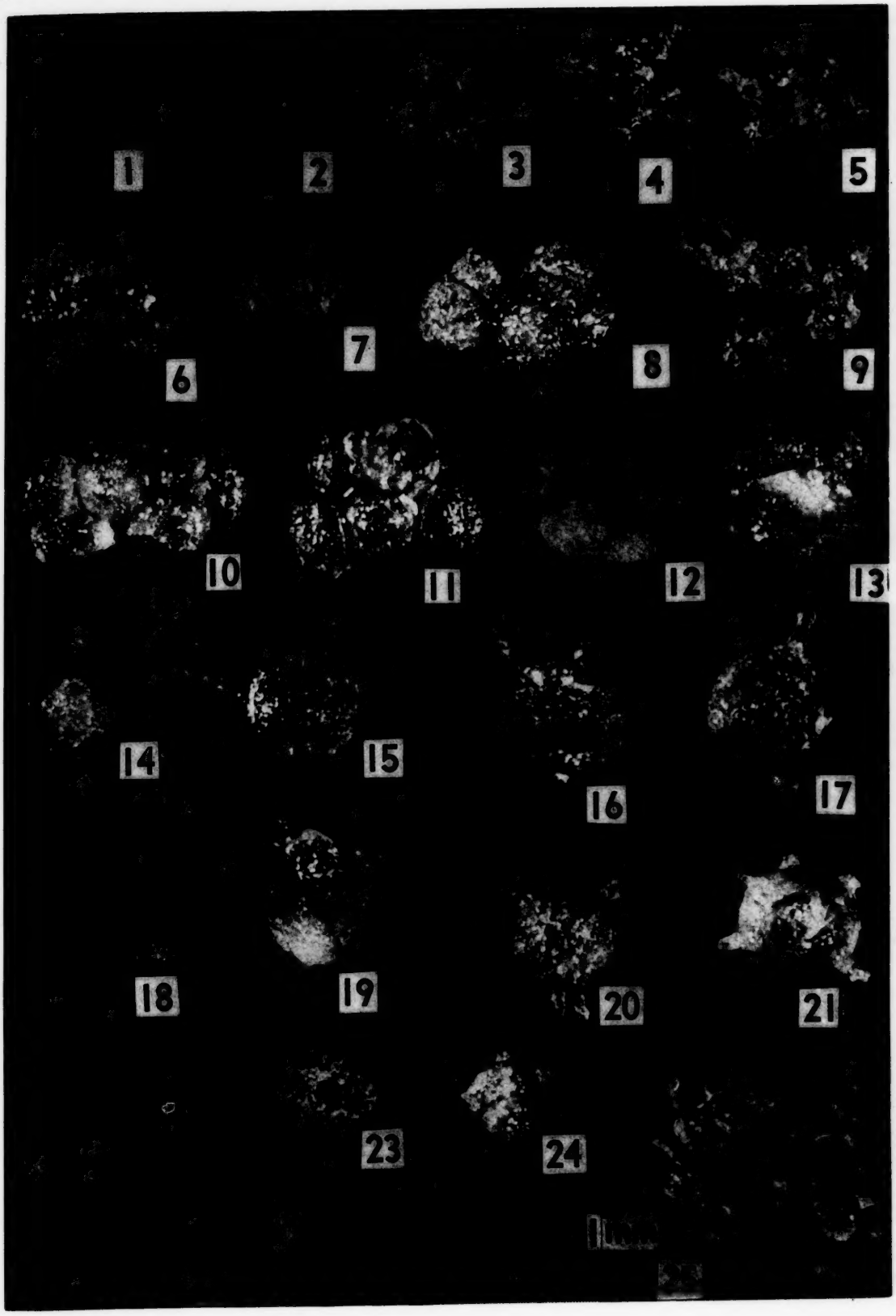
The diameter of the test is 0.80 mm. Its projections are 0.11 mm. in diameter at their base and 0.15 mm. long. The test wall is approximately 0.02 mm. thick.

The roughness of the interior and the many hollow protuberances suggest a labyrinthic test which is characteristic of *Thuramminoides.* Another interpretation is that the specimen might be a very bizarre form of *Thurammina* similar to *Thurammina papillata* Brady var. *castanea* Heron-Allen & Earland (1917) from Recent sediments in

EXPLANATION OF PLATE 33

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1–5—Pseudastrorhiza delicata* Gutschick & Treckman, n. sp. *1,* Photograph without glycerin; *2,* with glycerin; *3,* holotype; and *4,5,* paratypes. All specimens are from loc. 2.
6–7—Psammosphaera cava Moreman.
8–13—Sorosphaera papilla Gutschick & Treckman, n. sp. *8–10,12–13,* Paratypes; and *11,* holotype, from loc. 2.
14—Lagenammina sphaerica Moreman.
15—Thurammina diforamens Ireland.
16–17—Thurammina triradiata Gutschick & Treckman, n. sp. *16,* Paratype; and *17,* holotype, from loc. 1.
18—Thurammina quadritubulata Dunn.
19–20—Thurammina furcata Gutschick & Treckman, n. sp. *19,* Paratype; and *20,* holotype, from loc. 1.
22—Thurammina limbata Dunn.
23–24—Astrorhiza? sp.
25—Thuramminoides? sp.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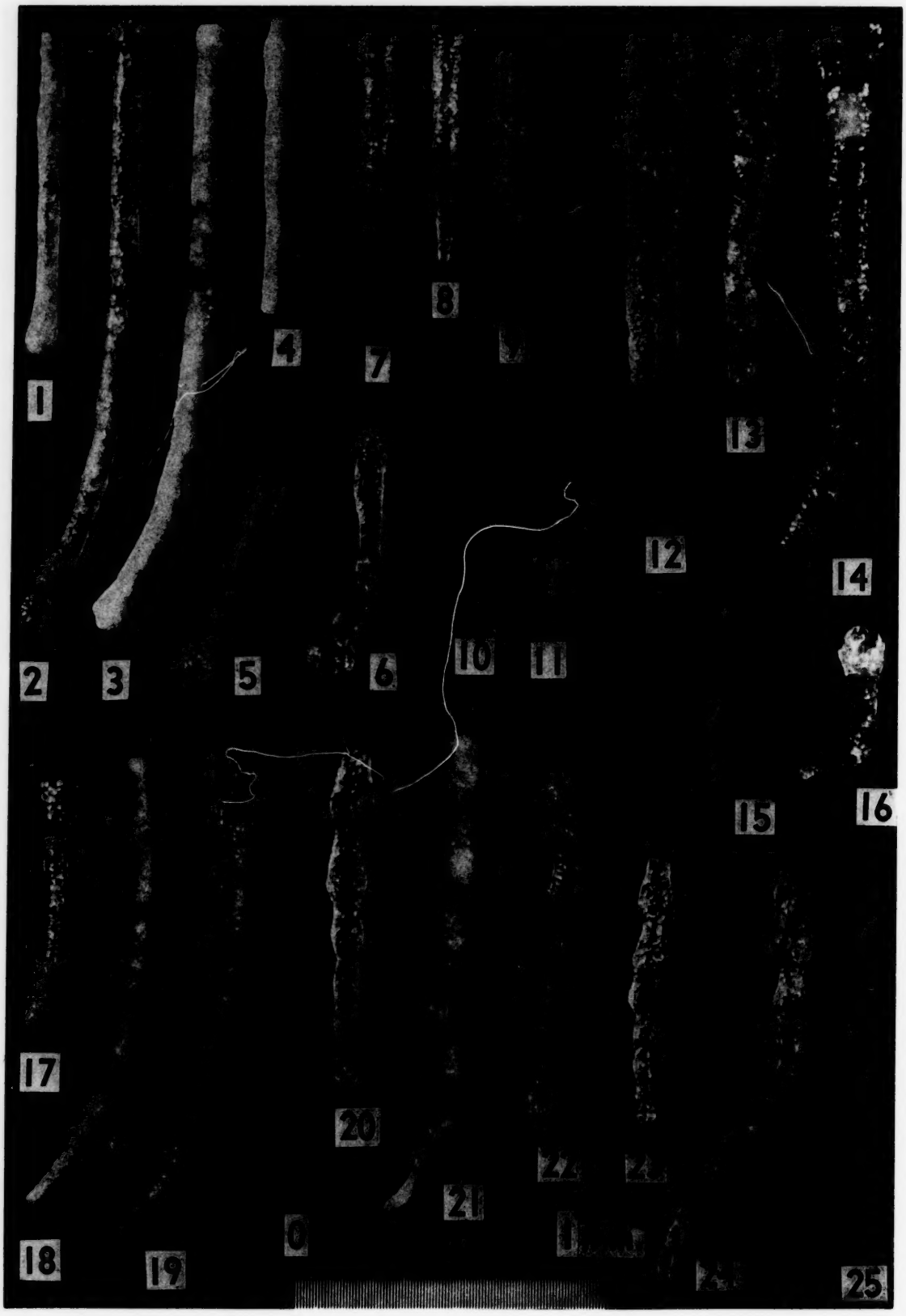
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the North Sea. The specimen came from the Remington locality.

Family HYPERAMMINIDAE Eimer & Fickert, 1899

Subfamily HYPERAMMININAE Cushman, 1910

Genus HYPERAMMINA H. B. Brady, 1878

HYPERAMMINA BULBOSA Cushman & Waters

Pl. 34, fig. 6

Hyperammina bulbosa CUSHMAN & WATERS, 1927, Cushman Lab. Foram. Res., Contrib., v. 3, p. 109, pl. 22, fig. 7.

"Test with a fairly large proloculum broader than the tubular second chamber, flattened at one side, convex on the other, the tubular chamber nearly circular in transverse section; wall arenaceous; aperture formed by the open end of the tube. Length variable, diameter of the tubular chamber 0.10 mm.

"The peculiar shape of the proloculus seems to be constant and unusual character. The tubular chamber has a somewhat sinuous border with regular enlargements and contractions of small amount but noticeable. These do not represent chamber diversions."

The holotype is from the Middle Pennsylvanian Saginaw formation from near Grand Ledge, Michigan.

The maximum diameter of the proloculus of the Rockford specimen is 0.175 mm. and the diameter of the tube is 0.10 mm.

Remarks.—The shape is characteristic of the type but the form is not common in the collection and may represent a variation of the *Hyperammina rockfordensis* type.

Occurrence.—Species occurs in both localities.

HYPERAMMINA COMPACTA Gutschick & Treckman, n. sp.

Pl. 34, figs. 12–16, text fig. 1—J–L

The test is free. It is large, robust, straight to slightly curved, and consists of an inconspicuous ovoid proloculus with a gradually tapering second chamber which is circular in cross section. There is very slight to no constriction between the proloculus and the second chamber. The later has occasional faint rugose growth enlargements along its length and terminates at the apertural expanded open end. The test is often sheared and offset in one or more places and recemented (Pl. 34, fig. 14). The wall is thick and is composed of fine well cemented sand. It has a granular exterior surface and the interior is rough. The color is grayish-orange.

The following measurements refer to the figured specimens. All measurements are in millimeters.

	Pl. 34 fig. 12 Paratype	Pl. 34 fig. 13 Paratype	Pl. 34 fig. 14 Holotype
Length of test	1.6	1.25	2.0
Maximum diameter	0.21	0.20	0.23
Diameter of proloculus	—	0.10	0.10

Thickness of wall measured on a mature specimen is 0.05 mm.

Remarks.—This species is characterized by its massive robust appearance and inconspicuous proloculus which is not separate from the second chamber by the usual external constriction. It also has thick walls

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EXPLANATION OF PLATE 34

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1–5—Hyperammina rockfordensis* Gutschick & Treckman, n. sp. *1,5*, Specimens with well developed proluculus; *2,3*, complete specimen; holotype from loc. 1; and *4*, microspheric form (?).

6—Hyperammina bulbosa Cushman & Waters.

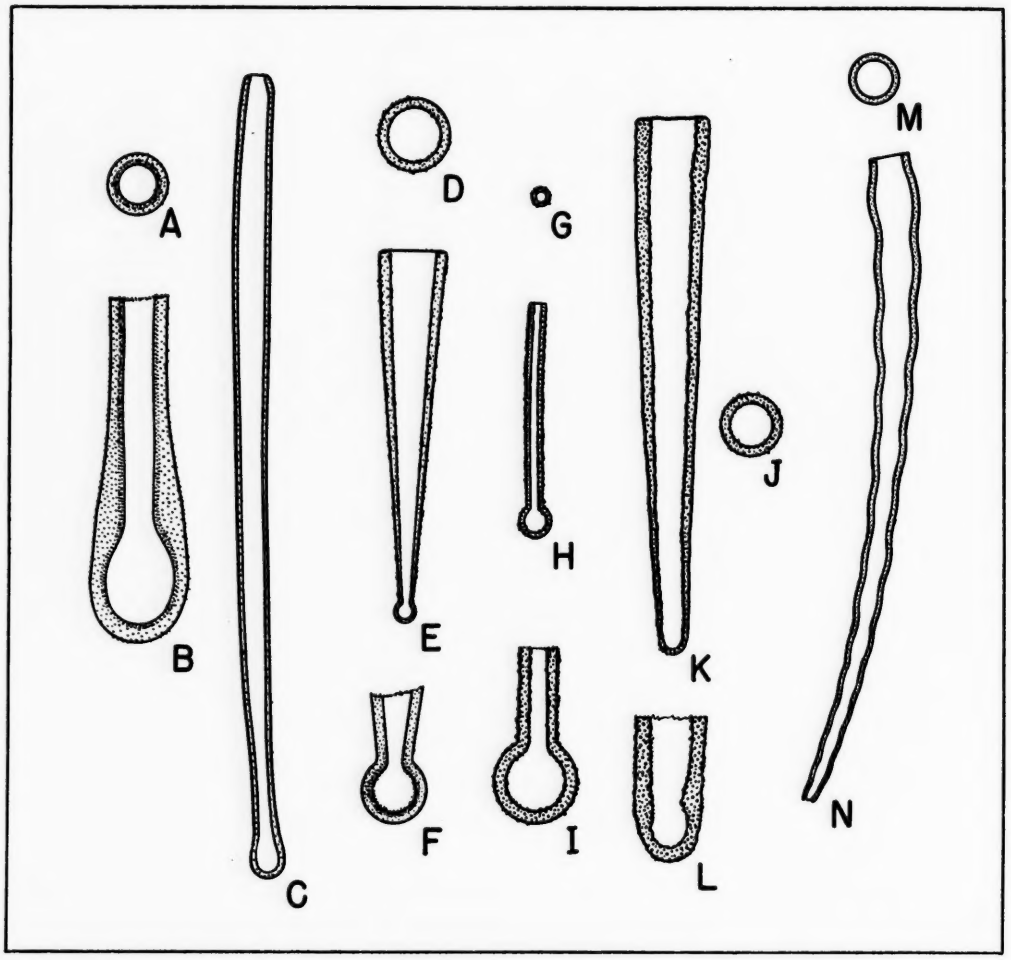
7–9—Hyperammina nitida Gutschick & Treckman, n. sp. *7*, Holotype, megalospheric form from loc. 1; *8*, paratype; *9*, paratype, microspheric form.

10,11—Hyperammina gracilenta Gutschick & Treckman, n. sp. *10,11*, Paratypes.

12–16—Hyperammina compacta Gutschick & Treckman, n. sp. *12*, Paratype, large specimen; *13*, paratype, illustrates nature of proloculus and second chamber; *14*, holotype, from loc. 1 shows healed shears; and *15,16*, immature (?) specimen.

17–19—Hyperammina constricta Gutschick & Treckman, n. sp. *17,19*, Paratypes from loc. 2; and *18*, holotype from loc. 1.

20–25—Reophax lachrymosa Gutschick & Treckman, n. sp. *20*, Holotype from loc. 2; *21,23–25*, paratypes; and *22*, incomplete specimen illustrates large size of chambers.



TEXT-FIG. *1*—Generalized sketch of Mississippian Rockford hyperamminids. (Sketched from transmitted light; specimens mounted whole in Lakeside Cement.)

A–C. *Hyperammina rockfordensis* Gutschick & Treckman, n. sp. A, Circular cross-section. B, Enlarged longitudinal section of proloculus (ca. ×150) showing reinforced wall between proloculus and second chamber. C, Section of complete specimen.

D–F. *Hyperammina nitida* Gutschick & Treckman, n. sp. D, Circular cross-section. E, Longitudinal section of megalospheric test. F, Enlarged section of proloculus.

G–I. *Hyperammina gracilenta* Gutschick & Treckman, n. sp., from the Welden limestone of Oklahoma. G, Circular cross-section. H, Longitudinal section. I, Enlarged section of proloculus.

J–L. *Hyperammina compacta* Gutschick & Treckman, n. sp. J, Circular cross-section. K, Longitudinal section. L, Enlarged section of proloculur showing lack of reflection of proloculus externally.

M,N. *Hyperammina constricta* Gutschick & Treckman, n. sp. M, Circular cross-section. N, Longitudinal section showing nature of second chamber.

which have a uniformly granular surface much coarser than any of the other Rockford hyperamminids. *Hyperammina compacta* resembles *Hyperammina harrisi* Ireland (1939) from the Lower Silurian of Oklahoma but the latter is smaller, has a narrower apertural end, is more cylindrical, and shows some constriction between the two chambers.

Occurrence.—The species is present at both localities. The holotype and paratypes are from the Alter's section.

HYPERAMMINA CONSTRICTA Gutschick & Treckman, n. sp.
Pl. 34, figs. 17–19; text fig. 1—M–N

The test is free. The proloculus has not been observed, but the second chamber is long, slender, circular in cross-section, gently tapering, slightly curved, and marked with regular constrictions. The interior of the second chamber is non-camerate. The small proximal diameter of the second chamber suggests that the initial chamber is very small and fragile. The aperture is at the open end of the expanded second chamber. The thin wall is smooth, glossy, translucent, irridescent, and is composed of well-cemented silt grains. The color of the test is white with occasional grayish-orange growth streaks.

The following measurements refer to the figured specimens and are in millimeters:

	Pl. 34		
	fig. 17	fig. 18 Holotype	fig. 19 Paratype
Length of test less proloculus	0.82	1.40	1.60
Maximum diameter	0.09	0.10	0.11
Minimum diameter	0.04	0.04	0.04
Length of swellings	—	0.125	—

The wall thickness at the mature end is 0.02 mm. Specimens have been found that measure 2.2 mm. in length.

Remarks.—Normally hyperamminids do not have such pronounced and regular constrictions and yet this form does not have the broad stoloniferous necks internally which characterize the reophacids. The specimens resemble *Chitinosiphon rufescens* Thalmann & Bermudez (1954) which is an entirely chitinous Recent rhizamminid. The smooth glossy translucent irridescent test suggests a chitinous composition, but high magnification with the petrographic microscope reveals an agglutinate quartz grain granular test. This form seems to be intermediate in development between the hyperamminids and the reophacids. Unless there has been replacement, the siliceous composition of the test rules out such genera as *Earlandia*, *Earlandinita*, and *Nodosinella*.

Occurrence.—The species occurs at both localities.

HYPERAMMINA GRACILENTA Gutschick & Treckman, n. sp.
Pl. 34, figs. 10,11; text fig. 1—G–I

This small fragile test consists of a spherical conspicuous proloculus and a slender straight to slightly curved second chamber. The junction between the two chambers is sharp. The megalospheric form has an even cylindrical second chamber, whereas the microspheric form has a slightly expanded second chamber. The thin wall is composed of well cemented silt to fine sand grains and has a granular surface. The color of the test is white to grayish-orange.

Measurements of figured Rockford specimens are given below along with those of the types from the Welden limestone of the type area in southern Oklahoma.

	Pl. 34			
	Rockford limestone		Welden limestone	
	fig. 10	fig. 11	Megalospheric Holotype	Microspheric
Length of test	0.46	0.70	0.97	0.60
Diameter of proloculus	0.08	0.075	0.11	0.04
Diameter of second chamber	0.04	0.045	0.075	0.05

Remarks.—This form is unique and different than any other Paleozoic forms of the genus. Only three incomplete specimens were recovered from the Rockford residues; however excellent specimens were obtained from the Welden limestone of Oklahoma where it is very common and better preserved. The Rockford specimens seem to be more fragile than those from the Welden and undoubtedly account for its scarcity in the Rockford.

Occurrence.—Only three specimens were found in the Rockford limestone from both localities; however the species is common in the Welden limestone of Oklahoma and the types have been selected from the latter

place (see text-fig. 1—G–I for illustrations of type specimen).

HYPERAMMINA NITIDA Gutschick & Treckman, n. sp.
Pl. 34, figs. 7–9; text fig. 1—D–F

The test is free. This elongate form consists of a small spherical proloculus and a narrow conical even-tapering second chamber with circular cross-section. The latter terminates in an aperture at the larger open end. Microspheric and megalospheric forms have been recognized. The test wall is thin at the neck adjacent to the proloculus but becomes moderately thick towards the expanded end. It is firmly cemented with very fine silt grains. Forms mounted in Lakeside Cement have an irridescent appearance which suggests a chitinous base. The apertural end is usually broken. The test is white with streaks of limonite weathered from the partly ferruginous cement.

Measurements of the figured specimens are as follows:

	Pl. 34		
	fig. 7 Holotype	fig. 8	fig. 9
Length of test	0.99	0.80	0.89
Max. diameter of test	0.15	0.12	0.14
Diameter of proloculus	0.06	—	0.04
Diameter of neck	0.045	—	0.03

Wall thickness varies from 0.01–0.03 mm. in a mature test.

Remarks.—This form closely resembles *Earlandia minuta* (Cushman & Waters) Plummer (1945) in appearance and measurements except that *Earlandia minuta* has granular calcareous wall structure and is constricted at the apertural margin. *Hyperammina nitida* also resembles *Hyperammina johnsvalleyensis* Harlton (1933) but the latter is much larger and has a greater diameter of test at the apertural end.

Occurrence.—All figured specimens including the holotype are from Alter's section.

HYPERAMMINA ROCKFORDENSIS Gutschick & Treckman, n. sp.
Pl. 34, figs. 1–5; text fig. 1—A–C

The test is free. It consists of a bulbous proloculus which is either spherical or ellipsoidal and a long slender straight to slightly curved gently tapering second chamber. This elongate chamber has slight "hour glass" constriction close to the proloculus and its greatest diameter is near the apertural end but the amount of distal expansion is slight. The surface of the test is smooth except for occasional constrictions. The aperture at the terminal end of the second chamber is of smaller diameter than the chamber. It also has a slight lip. The thin test wall is composed of well cemented very fine granular silt and there is some suggestion of a chitinous inner wall. The test is white to cream color.

Measurements of figured specimens are as follows:

	Pl. 34			
	fig. 1	fig. 2 Holotype	fig. 4	fig. 5
Length of test	1.0	1.95	0.9	1.0
Maximum diameter second chamber	0.09	0.11	0.11	0.11
Minimum diameter second chamber	0.07	0.08	—	0.09
Diameter of proloculus	0.11	0.11	—	0.13
Diameter of aperture	—	0.05	0.07	—

Remarks.—This is the most common hyperamminid in the Rockford limestone but due to its fragile nature, it occurs chiefly as fragments. Whole specimens are uncommon. It is most similar if not identical with *Hyperammina elegans* Rauser-Cernoussova & Reitlinger (1937) except the Rockford forms are larger and not of uniform diameter throughout. Another very closely related species is *Hyperammina kentuckyensis* Conkin (1954) which has greater expansion and more constrictions of the second chamber. *Hyperammina rockfordensis* has been recognized in the Coldwater shale of Michigan, Lodgepole limestone of Montana, Welden limestone of Oklahoma, and the Chappel limestone of Texas. There is some similarity in form with *Rhabdochitin minnesotensis* Stauffer from the Ordovician except the Ordovician form is entirely chitinous.

Occurrence.—This species is common in both localities. The holotype is from the Alter's section.

HYPERAMMINA? sp.
Pl. 37, fig. 10

The test closely resembles *Hyperammina constricta*, n. sp., except that it is larger, has fewer constrictions, and is attached throughout its entire length. The test is long, linear, slightly curved, and occasionally constricted. Although the proloculus is often broken, it is small and prolate. The test is attached to a thin calcareous rod which dissolves in acid leaving only the convex unattached portion of the test. The moderately thick test wall is made up of well cemented fine silt. Its surface is smooth. The test color is white and has an irridescent luster. This species is found in both localities.

Subfamily REOPHACINAE Cushman, 1927
Genus REOPHAX Montfort, 1808
REOPHAX BUCCINA Gutschick & Treckman n. sp.
Pl. 38, figs. 1–3; text fig. 2—C

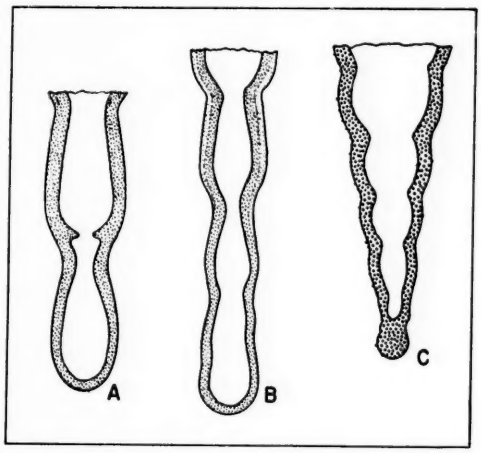
The test is free and linear. It consists of a spherical proloculus and a straight to gently curved second chamber. The latter starts out undivided like the hyperamminids so that the initial one-third of the test is more or less unconstricted and very translucent. The remaining two-thirds becomes constricted by broad stoloniferous necks to form rapidly expanding chambers. The expanded oblate chambers which are circular in cross-section average in width from one-half to two-thirds their height and are five to seven in number. Internally the chambers are not separated by cross-partitions but there are some indication of occasional short septal projections particularly in the more mature portions of the test. The aperture which is terminal appears to be the open end of the last chamber although many tests have this portion broken off. It is not clear whether or not this terminal chamber is constricted with smaller opening. The thick wall is composed of fine subangular sand grains. They are well cemented by siliceous material which lends gloss to the wall surface but does not envelop the larger grains which stand in relief. The color of the test is white to grayish-orange.

The following measurements were made on the figured specimens:

	Pl. 35 fig. 1	Pl. 35 fig. 2 Holotype	Pl. 35 fig. 3
Length of test	1.35	1.00	0.97
Maximum diameter	0.50	0.26	0.24
Diameter of proloculus	0.10	0.08	0.10

The wall thickness is variable. In the mature portion of the test it measures 0.05 mm.

Remarks.—Although there have been a great number of species described for this genus, *Reophax buccina*, n. sp., seems to bear little resemblance to any of them and especially the Paleozoic forms. Perhaps the closest species is *Reophax minutissimus* Plummer (1945) but it has a much thinner wall, is smaller, lacks the hyperamminid early stage, and does not expand as rapidly as *Reophax buccina*. This species suggests the genus *Hyperamminoides;* however the status of *Hyperamminoides* is not clear (Conkin, 1954; 1956 and Cummings, 1955. Rockford specimens were placed in *Reophax* rather than *Hyperamminoides* because the con-



TEXT-FIG. 2—Generalized sketch showing details of Mississippian Rockford reophacids. (Sketched from transmitted light; specimens mounted whole in Lakeside Cement.)

A,B. *Reophax lachrymosa* Gutschick & Treckman, n. sp., enlarged longitudinal sections (ca. ×100). A, Proloculus and first chamber showing internal constriction which may be secondary filling. B, Proloculus and first few chambers with indication of a two layered wall.

C. *Reophax buccina* Gutschick & Treckman, n. sp., enlarged longitudinal section (ca. ×30) with apertural portion broken off.

strictions and consequent chamber arrangement is more regular and there is some tendency for the animal to develop primitive small horizontal septa in the late growth stages. The specific name was chosen because the test is trumpet-shaped.

Occurrence.—This is a common species at both localities. Over fifty specimens were studied.

extraneous material including biotite flakes. Its surface is very finely granular. The color of the test is white.

Measurements of the figured specimens are as follows:

	Pl. 34			
	fig. 20 Holotype	fig. 21	fig. 22	fig. 23
Length of test	1.09	1.60	1.17	0.85
Number of chambers	5	8	4	5
Width of proloculus	0.10	0.065	—	0.085
Length of proloculus	0.17	0.11?	—	0.15

The following table gives the length, L, and width, W, of each chamber starting with the proloculus:

		Chamber						
		1	2	3	4	5	6	7
Fig. 20, pl. 34 (Holotype)	L	0.078	0.11	0.124	0.13	0.13	0.195	0.29
	W	0.065	0.085	0.095	0.10	0.117	0.11	
Fig. 22, pl. 34 (Paratype)	L	0.25	0.27	0.36	0.27			
	W	0.125	0.143	0.15	0.143			

REOPHAX LACHRYMOSA Gutschick & Treckman, n. sp.

Pl. 34, figs. 20–25, test fig. 2—A,B

The test is free. It is long and slender consisting of a spherical to prolate ellipsoidal proloculus and a linear series of gradually expanding pyriform chambers. The uniserial test is straight to gently curved and has a circular cross-section. The chambers which are separated by prominent shallow sutural constrictions average in width from one-half to two-thirds their height. They are joined end to end by partial overlap of the posterior extremity of each chamber over the protruding apertural extremity of the previous chamber so that the sutural constrictions are extended and neck-like. Single incomplete specimens have been found which have seven and eight chambers besides the proloculus. Fragmentary specimens exhibiting some of the largest chambers indicate that there must have been as many as eleven chambers on mature specimens. The aperture is at the open end of the last chamber and is apparently constricted. The shell wall consists of well-cemented silt size silica grains and other

The wall thickness in the mature test is 0.020 to 0.023 mm.

Remarks.—This species is assigned to *Reophax* because of the agglutinate nature of the wall and the uniserial chamber arrangement which manifests itself internally as broad stoloniferous neck-like separation of the chambers (Cummings, 1955, p. 234). *Reophax lachrymosa*, n. sp., is close if not identical to *Reophax bendensis* Plummer (1945) from the Lower Pennsylvanian Marble Falls formation of Texas; however the fragmentary and distorted nature of the types of the latter make it difficult to make a critical comparison. Perhaps the greatest difference between the two is in size. *Reophax bendensis* appears to be much larger than *Reophax lachrymosa*. In view of the excellent material available in the Rockford limestone and the inadequate description and type specimens of *Reophax bendensis*, it was decided to assign the Mississippian specimens to this new species. Fragments of the uniserial portion of *Ammobaculites* particularly *Ammobaculites pyriformis*, n. sp., are similar to *Reophax lachrymosa* except the latter is less coarse in texture and the proloculus is part of the uniserial test.

Occurrence.—This species is common in both localities.

REOPHAX? sp.
Pl. 35, figs. 4,5

The fauna contains one consistent form which is very similar to *Reophax buccina*, n. sp., except that it is vesicular and fragile. The test was undoubtedly composed of agglutinate lime sand grains of various sizes and shapes cemented together with a siliceous paste. The lime grains are dissolved in the acid leaving the insoluble cementing material to represent the shape of the test. The size and shape of the cavities in the test wall indicates that the arenaceous grains are poorly sorted bioclastic materials with many elongate grains. The test consists of a spherical proloculus with three to five globular chambers formed by the constriction of the wall which expands distally. It gets up to 1 mm. or more in length and the diameter is about one-third the length. In spite of the fragile nature of the fossil, over 15 specimens have been recovered from both localities.

While the form is recognized as being unique in the collection, it is not preserved well enough to warrant closer identification. It represents the insoluble product and may be later identified from unaltered thin-sections. *Reophax glennensis* (Harlton) Plummer (1945) from the Pennsylvanian of Texas is similar.

Family TOLYPAMMINIDAE Cushman, 1929
Subfamily INVOLUNTININAE Cushman, 1940
Genus AMMODISCELLA Ireland, 1956
AMMODISCELLA VIRGILENSIS Ireland
Pl. 35, figs. 15,16

Ammodiscella virgilensis IRELAND, 1956, Jour. Paleontology, v. 30, p. 845, text fig. 3—22–28.

"Test attached composed of proloculus and tubular second chamber coiled planispirally or with last one or two coils curving upward over the top of the test and overlapping the earlier coils; whorls range from four to six in number; wall composed of fine uniform quartz sand; surface smooth; aperture at the end of the last whorl."

Specimens come from the Upper Pennsylvanian Virgil series of Kansas.

The diameter of Rockford specimens varies from 0.22 to 0.50 mm.

Remarks.—This form is not common in the Rockford and its association with many specimens of *Tolypammina* does not exclude the possibility that it is merely an incomplete specimen of this genus. There is also some similarity with *Glomospira adherens* Parr (1942) from the Permian of Australia except in size.

Occurrence.—Species is present in the Alter's section.

Genus INVOLUTINA Terquem, 1862
INVOLUTINA EXSERTUS (Cushman) 1910
Pl. 35, figs. 8,9

Ammodiscus exsertus CUSHMAN, 1910, U. S. Nat. Mus., Bull., 71, pt. 1, p. 75, figs. 97a,b (in text): *idem.* Bull. 100, v. 4, p. 64, pl. 5, fig. 4; MOREMAN, 1930, Jour. Paleontology, v. 4, p. 58, pl. 7, figs. 4,8.

"Test free, consisting of an ovoid proloculus and tubular second chamber close coiled for several revolutions, then uncoiling, but in the same plane, uncoiled portion straight, of varying length and usually turned at right angles to the direction of coiling; wall composed of fine sand with much cement, surface smooth; aperture at the end of the uncoiled portion, circular and slightly constricted; color white. Diameter of figured specimen, 0.42 mm."

The holotype is of Recent age from off the coast of Honshu Island, Japan; whereas Moreman's specimens are out of the Lower Silurian Chimney Hill limestone of the Arbuckle Mts., Oklahoma.

Measurements of a typical Rockford specimen give length, 0.41 mm. and diameter, 0.33 mm. The diameter of the tubular neck is 0.05 to 0.06 mm.

Remarks.—This form may represent broken specimens of *Involutina longexsertus*, n. sp., but it seems common enough so as to make this less probable.

Occurrence.—The species occurs in the Alter's and Remington sections.

INVOLUTINA LONGEXSERTUS,
Gutschick & Treckman, n. sp.
Pl. 35, figs. 10–14

The free test consists of an ovoid proloculus and tubular second chamber which is closely coiled for several revolutions then uncoils but in the same plane. The uncoiled portion is straight and very long with its length greater than the diameter of the test. It is usually turned at right angles to the direction of coiling. The test wall is com-

posed of fine sand which is fairly well cemented. The proloculus is fragile. The aperture at the end of the uncoiled portion is circular in shape.

The length of the test is 0.50 to 0.91 mm.; its diameter is 0.21 to 0.27 mm. The diameter of the uncoiled tube is 0.06 to 0.07 mm.

Remarks.—This species is characterized by the exceptionally long, linear extension of the test; otherwise it is similar to *Involutina exsertus* (Cushman). The extension in *Involutina longexsertus*, n. sp., is usually greater than the diameter of the coiled portion.

Occurrence.—This species occurs in both places and is especially common in the Remington locality.

Involutina semiconstrictus (Waters), 1927
Pl. 35, figs. 6–7

Ammodiscus semiconstrictus Waters, 1927, Jour. Paleontology, v. 1, p. 132, pl. 22, fig. 1; *Involutina semiconstrictus* Loeblich & Tappan, 1954, Jour. Washington Acad. Sci., v. 44, no. 10, p. 306.

"Test nearly circular, planispiral biconcave; proloculus small, ovoid, tubular second chamber oval in transverse section, irregularly constricted, open at the terminal end, about nine coils in the adult test; wall coarsely arenaceous, the sand grains cemented with a small proportion of cement; aperture a circular opening at the end of the tubular chamber; color, white. Diameter of test, 1.0 mm.; diameter of tube at aperture, 0.1 mm.; thickness of wall at aperture, 0.03 mm."

The holotype is from the Lower Pennsylvanian Dornick Hills formation of the Ardmore Basin, Oklahoma.

The diameter of Rockford specimens varies from 0.32 to 0.50 mm.

Remarks.—Except for the smaller size of the Rockford specimens, they agree well with the shape and characteristics of the species.

Occurrence.—This species occurs at both localities.

Genus Glomospira Rzehak, 1888
Glomospira articulosa Plummer
Pl. 35, figs. 17–19

Glomospira articulosa Plummer, 1945, p. 233, pl. 16, figs. 21–25.

"This tight tangle of disorderly convolutions of a very slowly enlarging tubular chamber is the Gordian Knot of the foraminiferal structures in Pennsylvanian faunas in this area. It apparently follows no formal plan of coiling, but twists and turns about itself haphazardly, winding itself into a compact body of no definite shape. The shell wall is composed of very minute quartz particles bound by considerable clear and insoluble cement. Transverse constrictions are frequent but not consistently present. The whorl suture is sharply depressed. The aperture is the open end of the tube but can rarely be found."

This species is found in the Pennsylvanian strata of Texas.

Remarks.—There does not seem to be any regular character to this form on which to base a comparison. It does not look like any

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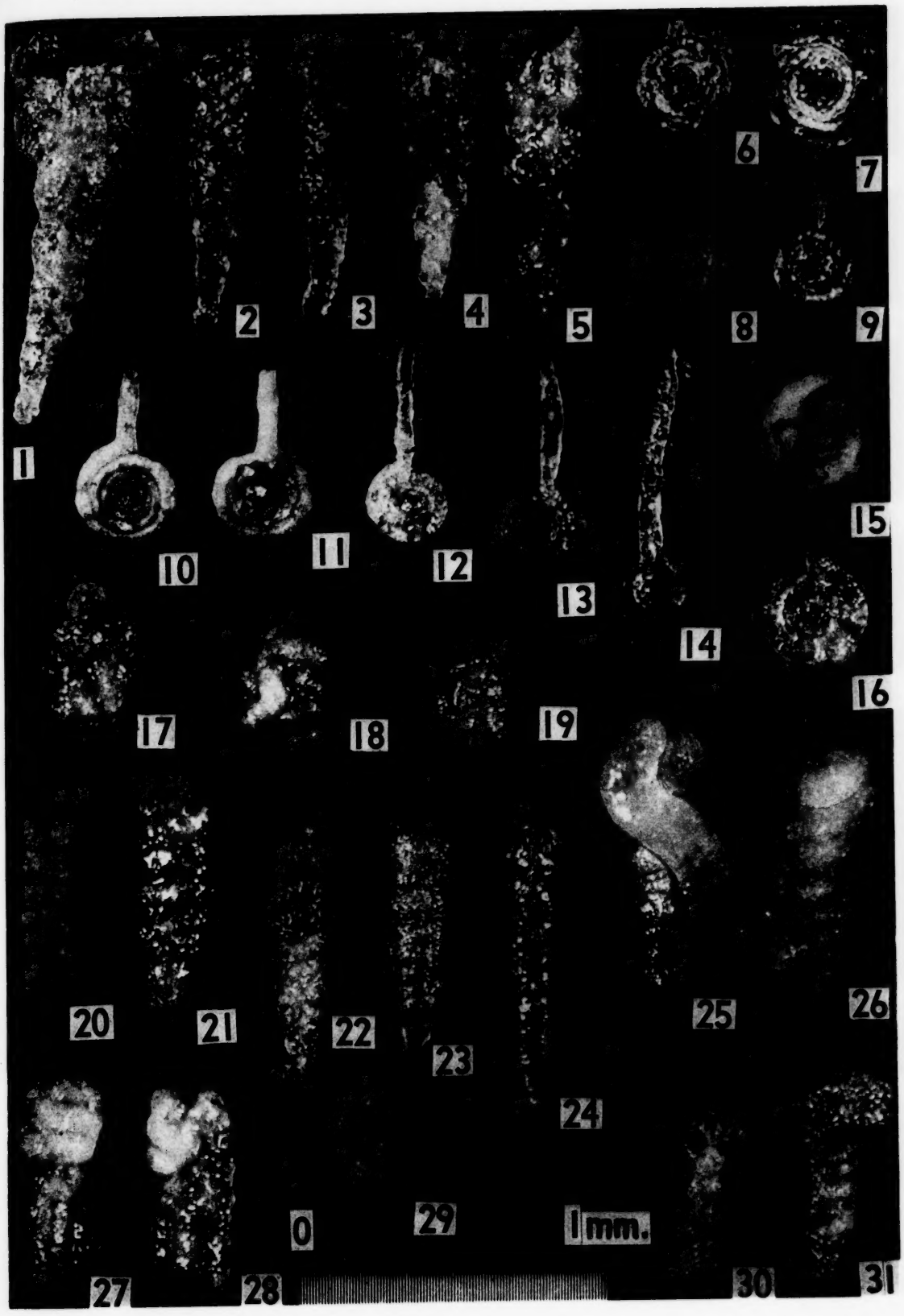
Explanation of Plate 35

All illustrations on this plate are unretouched photographs and are magnified ×50.

Figs. *1–3*—*Reophax buccina* Gutschick & Treckman, n. sp. *1*, Large mature specimen shows pronounced expansion and flare of late chambers; *2*, holotype from loc. 1; and *3*, paratype.
4,5—*Reophax?* sp. *4,5*, Specimens show porous nature of wall.
6,7—*Involutina semiconstrictus* (Waters)
8,9—*Involutina exsertus* (Cushman)
10–14—*Involutina longexsertus* Gutschick & Treckman, n. sp. *10,11*, Paratypes; *12*, holotype from loc. 2; and *13,14*, specimens from loc. 1 with compressed elongated chamber.
15,16—*Ammodiscella virgilensis* Ireland.
17–19—*Glomospira articulosa* Plummer.
20–24—*Trepeilopsis spiralis* Gutschick & Treckman, n. sp. *20,21,23,24*, Specimens which have been coiled about rods of different diameters; and *22*, holotype from loc. 1.
25,26—*Trepeilopsis recurvidens* Gutschick & Treckman, n. sp. Two lateral views of holotype, loc. 1.
27,28—*Trepeilopsis prodigalis* Gutschick & Treckman, n. sp. Two lateral views of holotype photo reversed with prolocular end up shows glomospiroid coiling of second chamber about prolocular portion of test, loc. 1.
29–31—*Trepeilopsis glomospiroides* Gutschick & Treckman, n. sp. *29,30*, Paratypes show glomospiroid apertural end; and *31*, holotype from loc. 1.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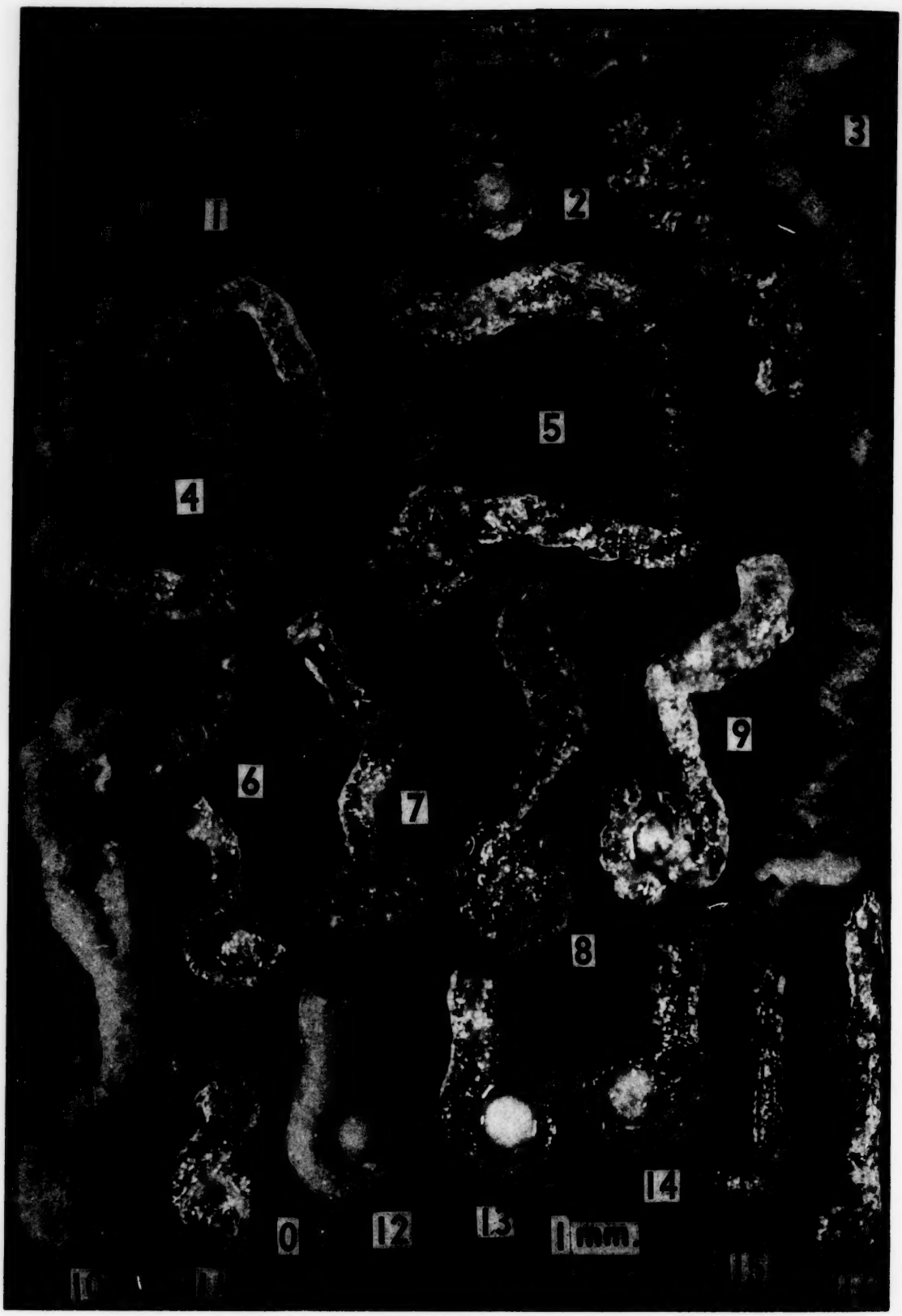
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other species of this genus and comes closest to *Glomospira articulosa* in having little pattern except that it is a rather compact wad of heterogeneously coiled chamber.

Occurrence.—The species is fairly common at both localities.

Genus TREPEILOPSIS Cushman & Waters, 1928

There is considerable variation in Rockford forms which is noted as follows. The animal may have difficulty in its earliest stage after it develops the proloculus in attaching itself to some spiny object such as a productid spine as has been noted by Cushman & Waters and Cooper. As a result, the earliest part of the second chamber is often somewhat disorganized before it develops regular spiral coiling around the spine. This may give the test a miniature glomospiroid appearance before the regular coiling. The diameter of the coiled portion is controlled by the size and shape of the spine as well as normal growth expansion. Spiral coiling is usually well organized and regular either sinistral or dextral. Many specimens have been found which terminate at the end of regular coiling. It is not entirely clear whether such test is complete with aperture or that it has been broken off. In some specimens it is also not clear whether they are attached or free. If free and completely elongate close spiral, they should be referred to *Turritellella*. Since most, if not all, of the Rockford specimens show evidence of a spine of attachment and are associated with abundant specimens clearly assignable to the genus *Trepeilopsis*, we are referring the close spiral tests also to *Trepeilopsis*. Another type of development is the typical characteristic of the genus in having the second chamber abruptly discontinue coiling and double back over the earlier whorls. This reversal may manifest itself in several ways. One form has the chamber swinging back and forth in the distal portion of the test over and around the expanded portion of regular coils in a glomospiroid manner (Pl. 35, figs. 29–31). Another form has a simple expanded S-shaped tube recurved back over the coiled test to the proloculus so that the aperture and proloculus are close together. Still another type is a continuation of such reversal whereby the terminal coiling becomes glomospiroid surrounding the proloculus and early portion of the test. Perhaps all of these types represent manifestations of the typical growth variations within one species; however since we have been able to recover many specimens of each type, it seems reasonable that they represent several species of the same genus.

TREPEILOPSIS GLOMOSPIROIDES Gutschick & Treckman, n. sp.
Pl. 55, figs. 29–31

The test is small and attached. It consists of a proloculus which is usually broken off and a second chamber which is closely coiled. The latter expands away from the proloculus. After six or eight whorls, the second chamber changes its style from regular to glomospiroid coiling. This results in a test enlarged at the distal end which is characteristic of the species. The aperture is at the open end of the tube. The fairly thick test wall is composed of well cemented, silt grains and has a finely granular surface. Its color is white to grayish-orange.

The following measurements are given for the figured specimens:

EXPLANATION OF PLATE 36

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1,2,4,6,7,10–14—Tolypammina cyclops* Gutschick & Treckman, n. sp. *1,2*, Two views to show both sides of test; *4*, characteristic separation of elongated second chamber from early portion of test; *6,7,11–14*, typical development of proloculus and first whorl; and *10*, holotype from loc. 1.

3—Tolypammina extenda Ireland.

5,8,9—Tolypammina rotula Gutschick & Treckman, n. sp. *5*, Mature specimen; and *8,9*, two views of holotype from loc. 1.

15,16—Tolypammina botonuncus Gutschick & Treckman, n. sp. *15*, Paratype; and *16*, holotype from loc. 1.

	Pl. 35		
	fig. 29	fig. 30	fig. 31 Holotype
Length of test	0.53 mm.	0.69 mm.	0.73
Maximum diameter	0.31	0.34	0.31
Diameter of proloculus	0.06	—	—

Remarks.—This form in its early regular coiling resembles the tests of *Trepeilopsis spiralis*, n. sp. It differs from any other species of the genus in the development of an enlarged distal portion of the test which resembles the test of *Glomospira* hence the specific name.

Occurrence.—This species is common at both localities.

TREPEILOPSIS PRODIGALIS Gutschick & Treckman, n. sp.
Pl. 35, figs. 27,28

The test is attached. Its early portion which is closely spiralled about a spine, gradually enlarges for six or eight whorls and then uncoils back towards the prolocular end where it again winds around the test in glomospiroid fashion. The globular wadded enlarged portion of the test is at the proximal end. The thick test wall is formed of well cemented silt grains and has a smooth to finely granular surface.

The length of the holotype (Pl. 35, figs. 27–28) is 0.72 mm. and its maximum diameter is 0.30 mm.

Remarks.—This species differs from all others of the genus in its development of a glomospiroid enlargement of the chamber over the proloculus and early portion of the test. This is in contrast to *Trepeilopsis glomospiroides*, n. sp., which has the enlargement over the opposite end.

Occurrence.—This species occurs in the Alter's section where it is uncommon.

TREPEILOPSIS RECURVIDENS Gutschick & Treckman, n. sp.
Pl. 35, figs. 25,26

The fairly large test is attached to a slender spine. Its proloculus is offset and the second chamber is tightly coiled in a conical spiral around the spine. After it coils for six to ten whorls, it then uncoils into a sinuous tube which extends backwards over the coiled portion towards the proloculus. The tube is circular, large, and simple. The thick test wall is composed of well cemented silt grains. Its surface is finely granular.

The length of the test is 0.90 mm.; its maximum width is 0.38 to 0.39 mm. There are nine whorls; the diameter of the tube in the last whorl is 0.17 mm.

Remarks.—*Trepeilopsis recurvidens*, n. sp., closely resembles *Trepeilopsis mississippiana* Cooper, 1947, from the Upper Mississippian Kinkaid formation of southern Illinois but the former is much larger. It is also similar to *Trepeilopsis prodigalis*, n. sp., but lacks the glomospiroid coiling over the prolocular portion of the test.

Occurrence.—This species occurs sparingly in both localities.

TREPEILOPSIS SPIRALIS Gutschick & Treckman, n. sp.
Pl. 35, figs. 20–24

The test is attached to a cylindrical spine probably a calcareous productid spine which dissolves out in acid and leaves a tubular central axial cavity. The test consists of a proloculus which is spherical. This proloculus becomes adherent to the spine hence it starts out off center to the axis of the test. The second chamber is a linear gradually expanding spiral. The early portion may be irregular but the animal develops even regular coiling about the rod of attachment fairly close to the proloculus. The chamber coils about the axis for some six to ten or more whorls. Occasionally there may be some crowded or loose coils. The apical angle varies depending on the size and shape of the rod of attachment. The aperture is at the end of the spiral tube. Many specimens have the proloculus broken off. The fairly thick test wall is composed of well cemented fine sand grains. Its surface is granular to slightly rough and it is white to light brown color.

Measurements of the figured specimens are given in table at the top of next page.

The diameter of the test wall is 0.03 mm.

Remarks.—This species resembles *Turritellella fisheri* Dunn and *Turritellella workmani* Dunn, 1942, from the Middle Silurian of Illinois; however, the tests of these species are free as compared to the attached test of *Trepeilopsis spiralis*. The latter is also larger in size.

Pl. 35

	fig. 20	fig. 21	fig. 22 Holotype	fig. 23	fig. 24
Length of test	0.74 mm.	0.77 mm.	0.94 mm.	0.82 mm.	1.03 mm.
Maximum diameter	0.25	0.26	0.24	0.24	0.24
No of whorls	5	6	10	10	11
Diameter of proloculus	—	—	—	—	0.06?

Occurrence.—This form is common at both localities.

Genus TOLYPAMMINA Rhumbler, 1895

We are following the diagnosis outlined by Ireland (1956, p. 838) for the characteristics of this genus. It must be realized that such vermicular adnascent tests show great variation which makes it very difficult taxonomically. We find that some Rockford tolypamminids contradict some of Ireland's criteria for distinguishing between *Tolypammina* and *Ammovertella*. The semi-circular cross-section of the tube is like *Ammovertella;* the presence of an agglutinate floor wall is like *Tolypammina.* Coiling in the early stages is characteristic of *Tolypammina;* however when the forms have one or two whorls in the early stage, a semi-circular second chamber, and may or may not have a wall along the surface of attachment, it is difficult to decide to which genus they belong. The attached tests, early development of coiling, and the late uncoiling into simple tube, not writhing, seems to favor their assignment with *Tolypammina.*

TOLYPAMMINA BOTONUNCUS Gutschick & Treckman, n. sp.
Pl. 36, figs. 15,16

The test is attached. It consists of a large spherical proloculus, less than one whorl of coiling, and a linear tapering uncoiled portion. The proloculus extends above the plane of the first whorl about half the diameter of the proloculus. The second chamber is coiled in an even whorl about three-fourths the way around the proloculus and then uncoils into a straight linear part which is narrow at the bend and gradually expands towards the aperture at the open end of the tube. The form of the test is clearly controlled by the object to which it is attached. The second chamber is semi-circular in cross-section and has a fragile wall along the floor of attachment composed of well cemented silt and fine sand grains. Its surface is smooth except for fine sand grains which are scattered over it. The color of the test is very light grayish-orange.

The following measurements are for the figured specimens.

Pl. 36

	fig. 15	fig. 16 Holotype
Length of test	1.2 mm.	0.85 mm.
Diameter of proloculus	0.14	0.15
Diameter of first whorl	0.22	0.24
Minimum diameter of second chamber	0.075	0.08
Maximum diameter of second chamber	0.13	0.14
Height of proloculus	0.15	0.16

Wall thickness is about 0.02 mm.

Remarks.—The species is characterized by its button-hook shape with less than one whorl of second chamber, constriction at its bend, and linear portion of the mature part of the test. It is similar to *Tolypammina cyclops*, n. sp., but does not have the complete coil around the proloculus, is smaller, and more unidirectional.

Occurrence.—The species occurs at both localities but it is not common.

TOLYPAMMINA CYCLOPS Gutschick & Treckman, n. sp.
Pl. 36, figs. 1,2,4,6,7,10–14

The large test is attached. It is composed of a large spherical proloculus and a wide tubular chamber which has the first whorl planispiral about the proloculus and then uncoils irregularly sinuous throughout its length. The proloculus is expanded and projects conspicuously above the floor of the test and the first whorl about half of its diameter. The first whorl is smoothly circu-

lar so that the proloculus looks like a large eye in this whorl. The second chamber uncoils to conform to the contour of the object of attachment and is occasionally slightly constricted once it leaves the first whorl. The test chamber is semi-circular in cross section with a flat portion which is the surface of attachment. The flat side may or may not have a wall. Often there is an agglutinate wall made up of silt to fine sand particles loosely cemented together; otherwise the object of attachment forms the floor of the test. Distally the second chamber may become unattached for a short length and it will have a circular cross section. The aperture is at the open end of the expanded tube. The thick wall is made up of well cemented silt to fine sand grains. Its surface is smooth to finely granular rough and colored white to grayish-orange.

The following measurements were made on figured specimens:

	Pl. 36					
	fig. 10 Holotype	11	12–14	6,7	1,2	4
Length of test	0.88	0.31	0.37	0.56	2.0	ca.2.0
Diameter of 1st whorl	0.21	0.15	0.21	0.18	0.25	0.26
Diameter of proloculus	0.11	0.09	0.075	0.075	0.13	0.15
Maximum diameter of chamber	0.09	0.075	0.09	0.06	0.20	0.19
Height of proloculus	0.12	0.11	0.10	0.09	0.13	0.15

The thickness of the wall is about 0.03 mm.

Remarks.—The species is characterized by the large spherical proloculus and the even circular, single whorl of the second chamber. The extended portion of the second chamber may vary considerably depending upon the shape of the object to which it becomes attached. This species resembles *Tolypammina grahamensis* Harlton, 1928, from the Upper Pennsylvanian of Texas but does not have a coiled proloculus. In addition the tubular second chamber has a more uniform diameter and the early stages of *Tolypammina cyclops*, n. sp., are very well developed showing clear relationship between proloculus and second chamber.

Occurrence.—This species is very common at both localities. The holotype is from the Alter's section.

TOLYPAMMINA EXTENDA Ireland
Pl. 36, fig. 3

Tolypammina extenda IRELAND, 1956, p. 849, text fig. 4—23,24.

"Test attached, consisting of proloculum with tubular second chamber coiled in the initial stage. A loosely winding early stage which extends in one direction; the extended portion may have a few twists or minor bands which do not deviate significantly from the general direction of growth. The tube enlarges very rapidly as the extended portion begins and then does not further enlarge. Walls of medium to fine quartz silt, well cemented; surface smooth to slightly rough; aperture at open end of tube."

The holotype is from the Pennsylvanian of Kansas.

The dimensions of the Rockford figured specimen are as follows. The length of the test is 2.8 mm. The maximum diameter of the second chamber is 0.20 mm. and its minimum diameter is 0.10 mm. The proloculus has not been observed, for the early coiling is glomospiroid and covers the initial chamber.

TOLYPAMMINA ROTULA Gutschick & Treckman, n. sp.
Pl. 36, figs. 5, 8–9;
Pl. 37, figs. 1–3

The test is attached. It consists of a moderate sized spherical proloculus and a second chamber which coils around the proloculus in two whorls and then uncoils in extended fashion to fit the contour of the object of attachment. Figures 1–3 show the effect that the object of attachment has on diverting the second chamber in its coiling. The second chamber may have slight constrictions and undulations. It is usually coiled so that it partly obscures the inner whorls and has a semi-circular cross-section. The aperture is at the open end of the tube. The thick wall is composed of well cemented silt and fine sand grains except for the floor of attachment where the wall is thin and the grains loosely cemented. The color of the test is white to grayish-orange.

Measurements of figured specimens are given:

	Pl. 36 fig. 5	Pl. 36 fig. 8 Holotype	Pl. 37 figs. 1–3
Length of test	2 mm.	1.5 mm.	1 mm.
Average diameter of coiled part	0.40	0.43	0.48
Diameter of proloculus	0.08	0.09	0.09
Maximum width of 2nd chamber	0.17	0.18	0.19

Remarks.—The species has moderate sized proloculus and two irregular complete whorls about the proloculus with extended mature part of the second chamber. It is similar to *Tolypammina delicata* Cushman & Waters, 1928, from the Pennsylvanian Cisco Division of Texas but the coiled portion is much larger and not planispiral. It is also more irregular in the Rockford specimens.

Occurrence.—This species is found in both localities.

TOLYPAMMINA sp. A
Pl. 37, figs. 6,7

The test is attached by a very small area and consists of a very large proloculus and a sinuous to tortuous but not coiled cylindrical second chamber. The wall is made up of silt grains, mostly quartz, but apparently there are some lime grains with siliceous cement. The aperture is circular at the open end of the tube. This form is not like anything described in the literature; however it is rare in both localities and usually broken so that good specimens are not available to serve as types. The test of one specimen is S-shaped.

TOLYPAMMINA sp. B
Pl. 37, fig. 11

The test consists of a large well formed translucent spherical proloculus and a very loosely spiralled second chamber coiled around a cylindrical spine of attachment. The second chamber is circular in cross-section. It makes two or three or more loose coils before it uncoils into a trail. The aperture is at the open end of the tube. The test wall is composed of well cemented silt grains and contains no lime grains as does *Tolypammina* sp. A. This form is so rare that it was not considered prudent to establish a new form based upon one or two specimens.

Genus AMMOVERTELLA Cushman, 1928
AMMOVERTELLA BULBOSA Gutschick & Treckman, n. sp.
Pl. 37, figs. 4,5, 8,9

The test is simple and attached. It consists of a large inflated spherical proloculus which shows no trace of attachment and a recurved second chamber which is attached throughout. The second chamber may have a thin wall along the floor covering the surface of attachment. It is semi-circular in cross section. The thin test wall is composed of well cemented fine silt grains and has a smooth surface. Its color is white to light brown.

Measurements of figured specimens is given below:

	Pl. 37 fig. 4	fig. 5	fig. 8	fig. 9 Holotype
Length of test	1.0	2.0	1.0	1.0
Diameter of proloculus	0.20	0.30	0.25	0.19
Maximum width of second chamber	0.15	0.34	0.20	0.16

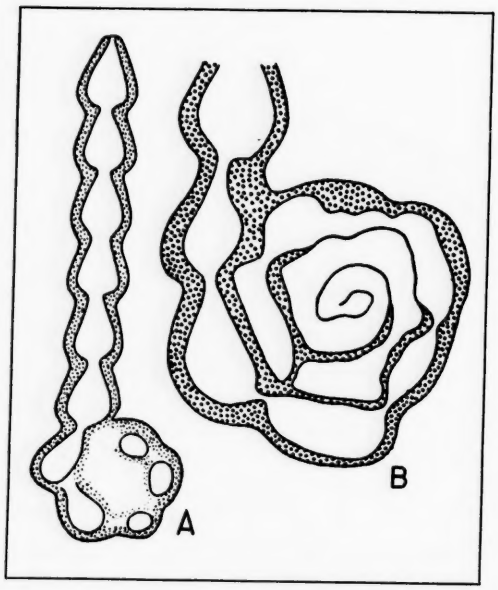
Wall thickness is about 0.025 mm.

Remarks.—This form was placed in the genus *Ammovertella* because it is attached, semi-circular in cross section, and is uncoiled. It resembles portions of *Ammovertella tornella* Ireland, 1956, but can hardly be described as coiling about a spine and is much larger.

Occurrence.—The species is common in both localities.

Family LITUOLIDAE Reuss, 1861
Subfamily HAPLOPHRAGMIINAE Cushman, 1927
Genus AMMOBACULITES Cushman, 1910
AMMOBACULITES LEPTOS Gutschick & Treckman, n. sp.
Pl. 37, figs. 12,13

The free test is planispiral, thin, slender and fragile. The early coiled portion is small and somewhat indistinct. While the coiled



TEXT-FIG. 3—Generalized sketch of *Ammobaculites pyriformis*, Gutschick & Treckman, n. sp. (Sketched from transmitted light; specimens mounted whole in Lakeside Cement.)
A. Longitudinal section showing pyriform chambers.
B. Enlarged view of planispiral portion of test showing coiling and chambers.

part is difficult to make out, there are four or five globular chambers discernible in the outer whorl. If there are any convolutions within the outer whorl, they are not apparent even with high magnification. The linear part of the test consists of 6 or more gradually enlarging chambers. These rectilinear chambers are pyriform in shape and circular in cross section. Their width is about one-half to two-thirds their length. The chambers are separated from each other by prominent constrictions. The aperture has not been observed with certainty because the largest chamber is usually broken but undoubtedly it is small, circular, and terminal to conform to the distal part of the chamber. The test wall is thin and consists of well cemented silt to fine sand grains. Its surface is rough and white in color.

Measurements of the figured specimens are given below:

	Pl. 37	
	fig. 12 Holotype	fig. 13
Length of test	0.86	1.08
Diameter of coiled portion	0.17	0.21
Max. diameter of chambers	0.10	0.12
Thickness of coiled portion	0.07	0.09

Thickness of wall is 0.015 mm.

Remarks.—This is the earliest occurrence of *Ammobaculites* in the published record. The species is characterized in that it is small and slender with pyriform chambers but often this is obscured by distortion due to crushing. There are only two species, *Ammobaculites fisheri* Crespin from the Lower Cretaceous of Australia, and *Ammobaculites inconspicuus* Cushman & Waters from the Middle Pennsylvanian Canyon Division of Texas, which are long and slender resembling *Ammobaculites leptos*, n. sp.; however both have oblate rather than prolate chambers as in the Rockford species. The uniserial portion of this species is similar to *Reophax lachrymosa*, n. sp., but they differ considerably in the early portion of the test.

Occurrence.—The species is found in both localities.

AMMOBACULITES PYRIFORMIS Gutschick & Treckman, n. sp.
Pl. 37, figs. 14–17,19,21–25; text fig. 3-A,B

The test is planispiral and consists of a coiled portion and a linear series of chambers. The coiled part appears to have three whorls from the proloculus outward to where it uncoils into the uniserial portion. The inner whorl is indistinct; whereas the middle whorl is partly evolute and recognizable. The outer whorl consists of four to six chambers. The linear series is made up of six or more pyriform slightly expanding chambers which are joined end to end by partial overlap. There is a tendency for the chambers to telescope probably due to the compaction of the enclosing sediments. The aperture has not been observed but must conform to the distal end of the chamber in being small and terminal. The test wall is thin and consists of well cemented silt to fine sand grains. It is smooth to granular and colored white.

Measurements of figured specimens are given in table at the top of next page.

Thickness of the test wall is 0.20 mm.

Remarks.—*Ammobaculites leptos*, n. sp., and *Ammobaculites pyriformis*, n. sp., are the oldest recorded species of this genus. *Ammobaculites fisheri* Crespin of the Lower Cretaceous of Australia, *Ammobaculites gracilis* Waters and *Ammobaculites inconspicuus* Cushman & Waters, from the Pennsylvanian of Texas are closest to *Ammobaculites pyriformis*, n. sp., but none of them has the prolate chambers of the latter. *Am-*

	Pl. 37			
	fig. 14	fig. 15	fig. 16	fig. 17
Length of test	0.97 mm.	0.88 mm.	0.75 mm.	1.05 mm.
Diameter of coiled portion	0.27	0.28	0.25	0.26
Maximum diameter of chambers	0.13	0.15	0.13	0.14

mobaculites pyriformis differs from *Ammobaculites leptos* in that the former is larger and more robust with better formed pear-shaped chambers. The former also has a larger coiled portion which bears more numerous chambers and whorls than *Ammobaculites leptos*. The uniserial part of this species also looks like *Reophax lachrymosa*, n. sp., but it is coarser and has shorter chambers.

Occurrence.—This species is common in both localities. The holotype, Plate 37, figure 14 is from the Alter's section.

AMMOBACULITES? sp.
Pl. 37, figs. 18,20,26,27

The test is free and consists of a planispirally coiled early portion followed by a uniserial series of chambers in its later development. Tests recovered from acid residues are very fragile. The coiled part of the test has a very delicate proloculus and inner whorls. These are usually broken and missing. It is estimated that the coiled portion of the test consists of three whorls. The test uncoils into a uniserial set of chambers but these are usually broken off so that only one or two are present. The chambers are longer than wide. Specimens recovered from acid residues are vesicular and indicate that the animal must have formed its test of agglutinate lime sand grains cemented together with a siliceous paste. It is the siliceous material which is preserved. The tests are white in color.

Measurements of figured specimens are given as follows:

	Pl. 37			
	fig. 18	fig. 20	fig. 26	Chappel* form
Length of test	—	0.33	0.39	0.70
Width of test	0.34	0.23	0.25	0.38
Thickness of test	—	0.085	0.075	0.12
Diameter of chambers	—	0.085	0.075	0.12
Length of chambers	—	0.12	0.12	0.12

* Specimen from the Chappel limestone of central Texas.

Remarks.—While this form is common, preservation is generally poor and the fragile nature of the test makes recovery difficult. Composition and nature of the wall structure have become important criteria for classification of the Foraminifera. If we are to regard these as important generic characteristics and recognize isomorphism as valid (Ireland, 1956; Cummings, 1955), then the Rockford form would become a new genus related to the agglutinate silica grained *Ammobaculites* and the calcareous test *Endothyranella*. The material at hand is too fragmentary to use for type specimens but merits inclusion in this report. This species has been recognized in the Welden limestone of Oklahoma and the Chappel limestone of central Texas where it is very abundant.

Occurrence.—This form is common in both localities.

REFERENCES

CONKIN, J. E., 1954, *Hyperammina kentuckyensis* n. sp. from the Mississippian of Kentucky, and discussion of *Hyperammina* and *Hyperamminoides:* Contrib. Cushman Found. Foram. Res., v. 4, p. 165–169, pl. 31.

——, 1956, *Nodosinella* Brady, 1876, and associated Upper Paleozoic general—a comment: Micropaleontologist, v. 2, p. 193.

——, 1957, Mississippian smaller Foraminifera of East-Central United States (abstract): Geol. Soc. America Bull., v. 68, p. 1889.

COOPER, C. L., 1947, Upper Kinkaid (Mississippian) microfauna from Johnson County, Illinois Jour. Paleontology, v. 21, p. 81–94.

——, 1948, Kinderhook micropaleontology: Jour. Geol., v. 56, p. 353–365.

CUMMINGS, ROBERT H., 1955, *Nodosinella* Brady, 1876, and associated Upper Paleozoic genera: Micropaleontology, v. 1, p. 221–238, pl. 1.

——, 1958, The faunal analysis and stratigraphic application of Upper Paleozoic smaller Foraminifera: Micropaleontology, v. 4, p. 1–24, pl. 1.

CUSHMAN, J. A. & WATERS, J. A., 1927, Pennsylvanian Foraminifera from Michigan: Contrib. Cushman Lab. Foram. Research, v. 3, p. 107–110.

——, & ——, 1928, Additional Cisco Foraminifera from Texas: Contrib. Cushman Lab. Foram. Res., v. 4, p. 62–67.

DUNN, P. H., 1942, Silurian Foraminifera of the Mississippi Basin: Jour. Paleontology, v. 16, p. 317–342, pls. 42–44.

GRUBBS, D. M., 1939, Fauna of the Niagaran nodules of the Chicago Area: Jour. Paleontology, v. 13, p. 543–560.

GUTSCHICK, R. C., 1954, Sponge spicules from the Lower Mississippian of Indiana and Kentucky: Am. Mid. Nat., v. 52, p. 501–509.

——, & TRECKMAN, J. F., 1957, Lower Mississippian cephalopods from the Rockford limestone of Northern Indiana: Jour. Paleontology, v. 31, p. 1148–1153, pls. 143–144.

——, & ——, 1957, Arenaceous Foraminifera from the Rockford limestone of Northern Indiana (Abstract): Geol. Soc. America Bull., v. 68, p. 1892.

HARLTON, B. H., 1928, Pennsylvanian Foraminifera from Oklahoma and Texas: Jour. Paleontology, v. 1, p. 305–310.

——, 1933, Micropaleontology of the Pennsylvanian Johns Valley shale of the Ouachita Mountains, Oklahoma, and its relationship to the Mississippian Caney shale: Jour. Paleontology, v. 7, p. 3–11.

HERON-ALLEN, E. & EARLAND, A., 1917, On some Foraminifera from the North Sea, etc., dredged by the Fisheries Cruiser "Goldseeker" (International North Sea Investigations—Scotland); Part V—On *Thurammina papillata* Brady: a study in variation: Roy. Micr. Soc. Jour., pt. 6, art. 10, p. 545.

IRELAND, H. A., 1939, Devonian and Silurian Foraminifera from Oklahoma: Jour. Paleontology, v. 13, p. 190–202.

——, 1956, Upper Pennsylvanian arenaceous Foraminifera from Kansas: Jour. Paleontology, v. 30, p. 831–864.

LOEBLICH, A. R., JR., & TAPPAN, H., 1954, Emendation of the Foraminiferal genera *Ammodiscus* Reuss, 1862, and *Involutina* Terquem, 1862: Jour. Washington Acad. Sci., v. 44, no. 10, p. 306–310.

MOREMAN, W. L., 1930, Arenaceous Foraminifera from the Ordovician and Silurian limestones of Oklahoma: Jour. Paleontology, v. 4, p. 42–59, pls. 5–7.

——, 1933, Arenaceous Foraminifera from the Lower Paleozoic rocks of Oklahoma: Jour. Paleontology, v. 7, p. 393–397, pl. 47.

PARR, W. J., 1942, Foraminifera and a tubiculous worm from the Permian of the North-West Division of Western Australia: Royal Soc. West. Australia, Jour., v. 27, p. 103.

PLUMMER, H. J., 1945, Smaller Foraminifera in the Marble Falls, Smithwick, and Lower Strawn strata around the Llano Uplift in Texas: Univ. Texas, Pub. 4401, p. 209–271, pls. 15–17.

RAUSER-CERNOUSSOVA, D. M. & REITLINGER, E. A., 1937 (in Fursenko, A. V.-ed.), Opredelitel foraminifer neftienosnikh raionov S. S. S. R.; chast I (Key to the Foraminifera of the oil-bearing regions of the U.S.S.R.) Moscow and Leningrad: ONTI (United Scient. and Tech. Press), pt. 1, p. 256.

SAID, RUSHDI, 1953, Foraminifera of Great Pond, East Falmouth, Massachusetts: Contrib. Cushman Found. Foram. Res., v. 4, p. 7–14.

SHROCK, R. R. & MALOTT, C. A., 1929(1930), Notes on some Northwestern Indiana Rock Exposures: Indiana Acad. Sci., Proc., v. 39, p. 221–227.

SUMMERSON, CHARLES, 1958, Arenaceous Foraminifera from the Middle Devonian limestones of Ohio: Jour. Paleontology, v. 32, p. 544–558, pls. 81–82.

THALMANN, H. E. & BERMUDEZ, P. J., 1954, *Chitinosiphon*, a new genus of the Rhizamminidae: Contrib. Cushman Found. Foram. Res., v. 5, p. 53–54.

WATERS, J. A., 1927, A group of Foraminifera from the Dornick Hills formation of the Ardmore Basin: Jour. Paleontology, v. 1, p. 129–133.

WOOD, A., 1949, The structure of the wall of the test in the Foraminifera, its value in classification: Geol. Soc. London, Quart. Jour., v. 104, p. 229–255.

WORKMAN, L. E. & GILLETTE, TRACEY, 1956, Subsurface stratigraphy of the Kinderhook Series of Illinois: Illinois Geol. Surv., Rept. Invest., 189, 46p., 2 pls.

EXPLANATION OF PLATE 37

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1–3—Tolypammina rotula* Gutschick & Treckman, n. sp.

4–5,8–9—Ammovertella bulbosa Gutschick & Treckman, n. sp. *4,5,8*, Paratypes; and *9*, holotype from loc. 1.

6,7—Tolypammina sp. A. Two views of same specimen without and with glycerin, note pores where lime grains have been dissolved out.

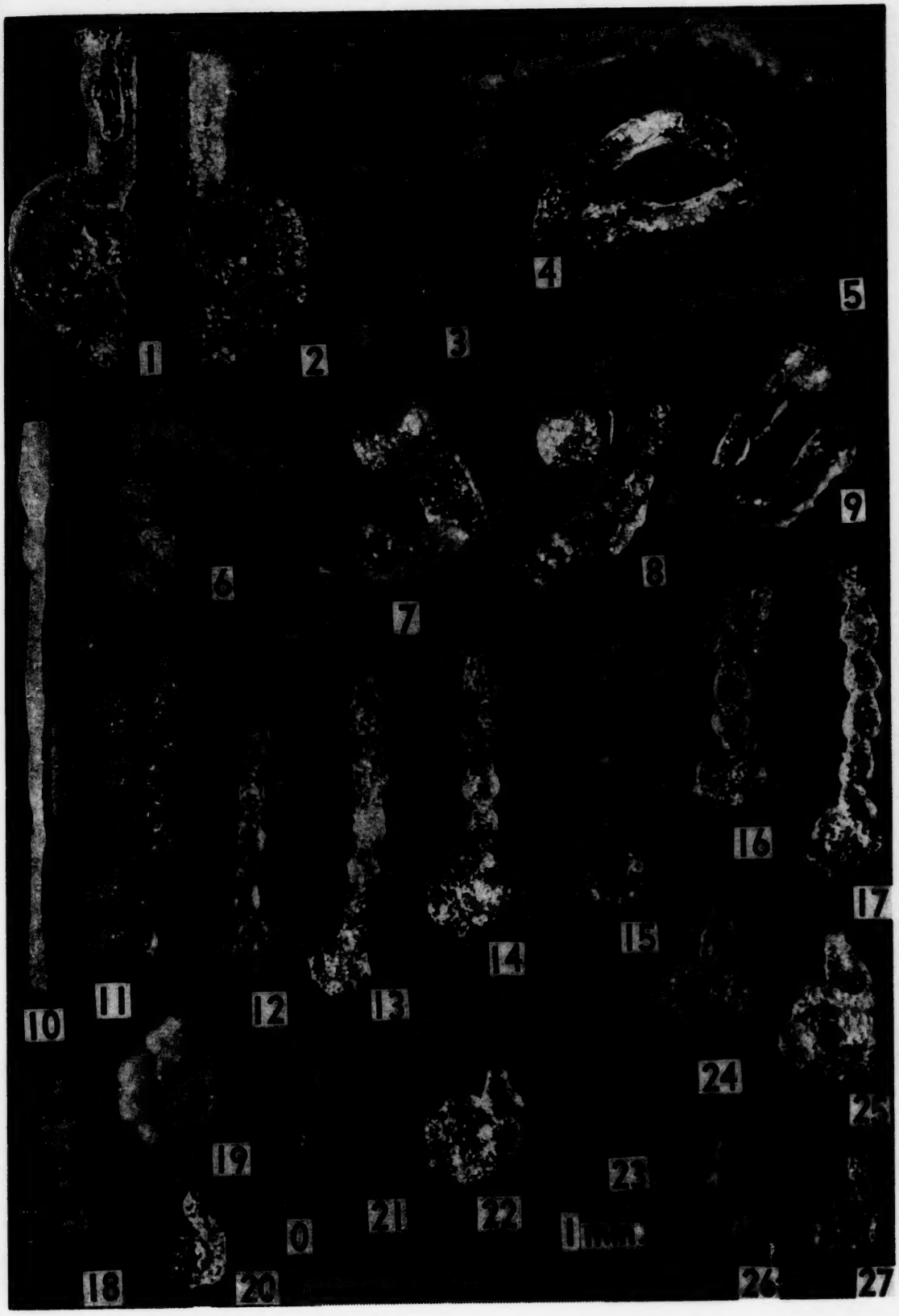
10—Hyperammina? sp. Specimen shows surface of attachment.

11—Tolypammina sp. B.

12,13—Ammobaculites leptos, Gutschick & Treckman, n. sp. *12*, Holotype from loc. 1; and *13*, larger paratype.

14–17,19,21–25—Ammobaculites pyriformis, Gutschick & Treckman, n. sp. *14*, Holotype from loc. 1; *15–17*, paratypes; and *19,21–25*, large specimens with uniserial portion broken off.

18,20,26–27—Ammobaculites? sp. Note porous nature of wall where lime grains have dissolved out.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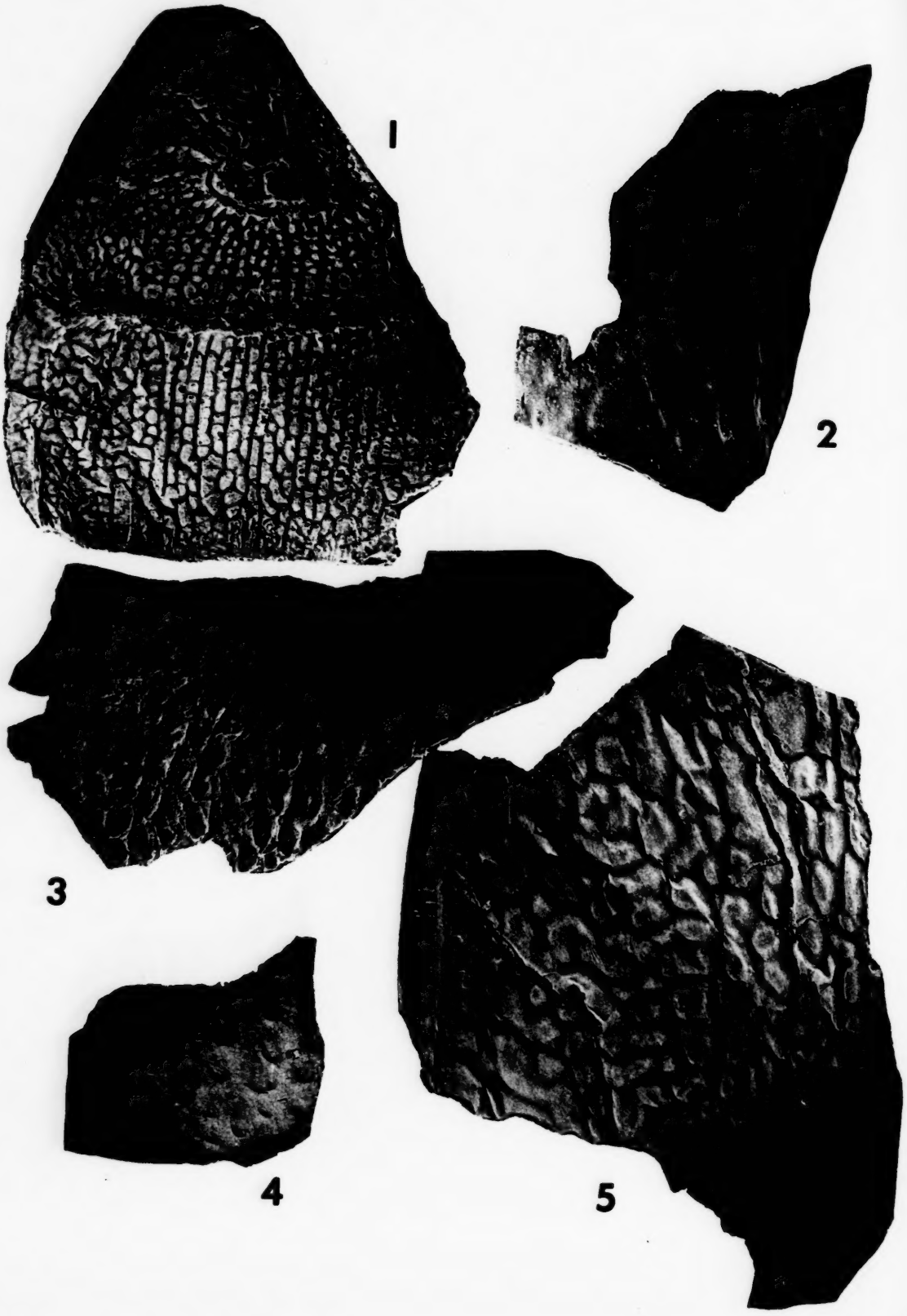
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A TAXONOMIC REVIEW OF SOME LATE PALEOZOIC EURYPTERIDA

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ABSTRACT—The type species of *Mycterops* Cope, 1886, (*M. ordinatus* Cope) is redescribed and refigured inasmuch as the original description and figures were inaccurate. The family Mycteropidae Cope, 1886, is emended to include only the genus *Mycterops* and is referred to the superfamily Eurypteracea Burmeister, 1845. *Mycterops? scabrosus* Woodward, previously included in the family Mycteropidae, is considered the genotype of a new genus, *Woodwardopterus*, which is referred to a new family, Woodwardopteridae, and delegated to the superfamily Stylonuracea Diener, 1924. *Campylocephalus scouleri* (Hibbert), hitherto mainly included in the family Stylonuridae Diener, 1924, is made the type species of a new genus, *Hibbertopterus*, which is included along with the genus *Campylocephalus* Eichwald, 1860, in a new family, Hibbertopteridae, and referred to the superfamily Stylonuracea Diener, 1924.

AMONG the more unusual, and consequently more problematical, Eurypterida are the larger forms found in Carboniferous and Permian strata. By far, the bulk of species found in these beds belong to the genus *Adelophthalmus* Jordan & Meyer, 1854, and has been the subject of several recent papers by Kjellesvig-Waering (1948), Pribyl (1952), and Van Oyen (1956). The genus *Adelophthalmus* is relatively common in contrast to other eurypterids in upper Paleozoic beds and is not considered a problematical group, although the number of species recognized is a matter still to be settled. Pribyl and the writer recognize approximately the same number of species, whereas Van Oyen (1956) has greatly reduced the number of species, in particular the North American representatives.

Our concern here, however, is with the rarer, and in the main, larger forms which are scattered in Carboniferous and Permian beds in North America, Scotland, and continental Europe.

One of the most interesting of these eurypterids was described by Cope in 1886, as a primitive vertebrate. He named the genus, *Mycterops*, with the species *M. ordinatus* as type species, and established the family Mycteropidae which he placed under the Class Agnatha. He followed this paper in 1888 with a comparison of his new fossil and other vertebrates. At the latter time, this was by no means an illogical conclusion as the eurypterid in question is one of the most peculiar known. Much has been learned about eurypterids and primitive fishes since that time. Unaware of Cope's papers, Pruvost (1925) recognized the eurypterid nature of a fossil from the Upper Carboniferous beds of Belgium, which not only was remarkably like Cope's *Mycterops ordinatus*, but which had preserved approximately the same morphological parts. He established

EXPLANATION OF PLATE 38

FIGS. *1–5*—*Mycterops ordinatus* Cope. *1*, Carapace and attached first tergite, lectotype, USNM 1997; *2*, fragment of a very large specimen apparently part of the carapace or a tergite (compare size of ornamentation with the lectotype), USNM 4544; *3,4*, scale-like ornamentation apparently from one of the posterior tergites, USNM 4543 and 1980; and *5*, fragment of left side of carapace retaining the marginal rim of a gigantic specimen (compare size of reticulated pattern with that of fig. 1), USNM 1978. All ×1. Darlington black shale, immediately below the Darlington coal, Allegheny formation, Pennsylvanian system, near Cannelton, Darlington township, Beaver County, Pennsylvania. All specimens are in the collections of the U. S. National Museum; collector, R. D. Lacoe.

the genus *Glaucodes*, with *G. mathieui* as type species.

Kjellesvig-Waering (1948) recognized, from a study of Cope's types at the U. S. National Museum, that the genus *Mycterops* Cope, 1886, was identical with *Glaucodes* Pruvost, 1925, and that the former has priority. Therefore, the generic name *Mycterops* should be used. Cope's figures, except for the ornamentation noted, are inadequate. The present writer would not have identified Cope's *Mycterops* with Pruvost's *Glaucodes* had he not had access to Cope's original material. Størmer established the family Mycteropidae in 1951 (pro Mycteropteridae Størmer, 1951) to include the genus *Mycterops*. He assigned with question to this genus *Stylonurus? scabrosus* (Woodward), a highly controversial form from the lower Carboniferous of Scotland. Because the latter retained well preserved walking legs of a distinctly stylonuroid type, he referred the Mycteropidae to the superfamily Stylonuracea. Størmer (1951), however, was unaware that Cope (1886) had previously established the Mycteropidae as a family of primitive vertebrates. Cope, therefore, must be credited with the family Mycteropidae, although he had not recognized the true nature of the family.

Pruvost (1925) and Kjellesvig-Waering (1948), basing their opinions on the classification of the Eurypterida known at the time (for example, 1925 and 1948) considered *Mycterops* to have affinities with the Carcinosomatidae, or within the superfamily Eurypteracea of present usage, whereas Størmer included the genus under the Stylonuracea. However, the latter designation was at least in part necessitated by the inclusion of an obvious Stylonuracea (*Stylonurus? scabrosus*) in the family Mycteropidae. The present writer considers that *Mycterops* and the peculiar *S.? scabrosus* should be separated and that the Mycteropidae Cope, 1886, should include only the genus *Mycterops* which should be assigned to the superfamily Eurypteracea. He further proposes that *S.? scabrosus* (Woodward) should be included in a new genus, herein named *Woodwardopterus*, and that a new family, Woodwardopteridae, should be established with *Woodwardopterus* as the type genus. Woodwardopteridae should be included within the Stylonuracea. Waterston (1957) in his excellent review of the Scottish Carboniferous Eurypterida refers *S.? scabrosus* to the *Mycteropidae* with considerable doubt. The question of the proper assignment of *Mycterops* to either the Eurypteracea or the Stylonuracea can be settled only with the discovery of the prosomal appendages. These have not been found to date, although Pruvost (1925, pl. 1) in his description and figure of *M. mathieui* illustrates a fragment which he determined as the sixth appendage. This comprises a flat plate-like appendage which could well be part of the swimming paddle of the eurypterid. If this interpretation is correct, then the Mycteropidae can safely be referred to the Eurypteracea.

Another peculiar and highly controversial form from the lower Carboniferous of Scotland was described as *Eidothea* by Scouler in 1831. Later Hibbert (1836) described the form as *Eurypterus scouleri*. Jordan & Meyer in 1854 were the first to recognize that *E. scouleri* properly should be placed in a separate genus from *Eurypterus*. Salter (1863) did not agree with Jordan & Meyer. Eichwald in 1860 recognized this form as a species of his genus *Campylocephalus*, which he had erected to accommodate the Russian species *Limulus oculatus* Kutorga. These determinations, however, did not become established, and Hibbert's species remained known as *Eurypterus scouleri* by all authors. Kjellesvig-Waering (1948) mentioned that the eurypterid did not show any affinities to the genus *Eurypterus*, and for the present (1948), the species should be treated as *Eurypterus? scouleri* Hibbert. Størmer (1951) recognizing that *Campylocephalus oculatus* (Kutorga) from the uppermost Carboniferous or lower Permian of Dourassoff, Urals, U.S.S.R., revealed distinct affinities with the Scottish *E.? scouleri* Hibbert, referred the latter to *Campylocephalus* and included the genus under the Stylonuracea. The writer agrees that *Campylocephalus* should be included in the Stylonuracea but, although the Russian Upper Carboniferous-Permian form and the Scottish Lower Carboniferous form reveal much in common, the two forms might best be separated into two distinct genera. The basis for separation is the form of the prosoma, the position, and the en-

tirely different structure of the compound eyes. He further proposes that both genera be included in a new family on the basis of the structure of the metastoma and other features described below. Thus, it is proposed that *Campylocephalus scouleri* be referred to a new genus, herein named *Hibbertopterus*, and that *Campylocephalus* Eichwald, 1860, should include only the type species *C. oculatus* (Kutorga). The determination of the metastoma by Waterston (1957) in *Hibbertopterus* is sufficient evidence for the separation of the latter and *Campylocephalus* from the Stylonuridae. Both genera should be referred to a new family, Hibbertopteridae, which is included under the superfamily Stylonuracea. In Waterston's recent monograph (1957), *H. scouleri* is included under the family Eurypteridae, thus within the Eurypteracea rather than the Stylonuracea. The form of the carapace, the type of compound eyes, and the very narrow mesosoma of *Hibbertopterus* indicate to the present writer affinities with the Stylonuracea rather than the Eurypteraces. The lack of knowledge of the nature of the sixth appendage in the Hibbertopteridae is, of course, of prime importance in determining this question. It might be added that, as pointed out by Størmer (1951), the genus *Tarsopterella* has much in common with *Campylocephalus* (and *Hibbertopterus*) and, when the underside of *Tarsopterella* is known, it may well be found that it should be included in the new family Hibbertopteridae herein proposed. The nature of the metastoma of *Tarsopterella* is of primary importance in this determination.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. G. Arthur Cooper of the U. S. National Museum for making available the types of *Mycterops ordinatus* Cope and for the photographs of the specimens illustrated on Plate 38.

SYSTEMATIC DESCRIPTIONS

Superfamily EURYPTERACEA Burmeister, 1845

Family MYCTEROPIDAE Cope, 1886, emend.

Eurypteracea of large size, outer surface covered with a reticulate pattern of ornamentation grading into coarse scales on the posterior tergites; prosoma trapezoidal; eyes and ocelli, close-set, centrally located; first tergite greatly expanded; prosomal appendages, underside, and most of opisthosoma beyond first tergite unknown.

Type species: *Mycterops* Cope, 1886.

Genus MYCTEROPS Cope, 1886

MYCTEROPS ORDINATUS Cope

Pl. 38, figs. 1–5

Mycterops ordinatus COPE, 1886, Am. Natur., v. 20, p. 1029–1030, fig. 1; ——, 1888, Am. Natur., v. 22, pl. XV, fig. 3; LESLEY, 1889, Pennsylvania Geol. Survey, Report P4, v. 1–3, p. 434–435, 1 fig.; MILLER, 1889, p. 602, fig. 1149; KJELLESVIG-WAERING, 1948, Illinois State Mus., Sci. Papers, v. 3, p. 7, STØRMER, 1955, Treatise Invert. Paleont., Part P, Arthropoda 2, p. 39; WATERSTON, 1957, Trans. Royal Soc. Edinburgh, v. 63, p. 285.

The lectotype, herein designated from a syntypic series of six specimens, is specimen No. 1977 in the U. S. National Museum collection and figured here on Plate 1, figure 1, comprises a fragment retaining most of the carapace with the compound eyes and ocelli, as well as most of the large first tergite. There seems to be little doubt that this specimen, which retains Cope's label reading "head," is the specimen from which his figure of the "skull" of *Mycterops ordinatus* was based (1886, fig. 1, and 1888, pl. XV, fig. 3). Five other fragments of the carapace and the tergites indicating the gigantic proportions of this eurypterid are also available for this description.

The carapace is trapezoidal in general outline. The base is curved outward in a gentle curve suggesting that this form was highly arched in an uncompressed state. The lateral margins converge forward, and are abruptly truncated by the anterior margin. A very narrow marginal rim surrounds the carapace. The compound eyes and ocelli are grouped together, almost centrally located on the carapace, but slightly behind the center. Each eye is reniform, relatively small, and parallel to one another. The ocelli are located midway between the eyes. They are unusually large, close-set, and closer to each other than to the compound eyes. A thickened cuticular rim occurs immediately behind the eyes and the ocelli in form of a bow connecting the posterior of the compound eyes.

The first tergite is enormously developed,

being nearly as long as the carapace. Greatest width occurs approximately at the central part, a radical departure from other Eurypterida where the greatest width of the mesosoma is nearly always developed at the posterior of the third tergite.

The distinct ornamentation comprises a reticulated pattern which radiates web-like, away from the area of the compound eyes and the ocelli. This pattern consists of flattened areas, more or less in rows, separated by narrow depressions, and each row is also broken into rough oblongs separated by similar depressions. The individual rows, particularly on the central part of the carapace, are roughly continuous with the rows on the central part of the tergite. To the sides of the carapace and tergites the ornamentation loses its distinct row-like arrangement, and here they become irregular flattened masses separated by similar narrow depressions (Pl. 38, fig. 1). Fragments of tergites with tear-drop scales, apparently referrable to this species, are illustrated on Plate 38, figures 3–4. These scales likely belong to the posterior part of the mesosoma, or more likely to the metasomal tergites.

Measurements of the lectotype are possible within a certain degree of accuracy although, because the specimen is incomplete, these measurements are mainly estimated:

Prosoma:

Length:	50.0 mm.
Width behind eyes:	73.0 mm.
Width at base:	82.0 mm.

Compound eyes are located on the prosoma:

From anterior:	From posterior:	From lateral:	Apart:
24.0 mm.	18.0 mm.	23.5 mm.	14.0 mm.
Length of compound eyes:		7.0 mm.	
Width of compound eyes:		4.0 mm.	

Ocelli are located on the prosoma:

From anterior:	From posterior:	From lateral:
28.0 mm.	20.0 mm.	32.5 mm.
Diameter of ocelli:		2.0 mm.

1st tergite:

Length	39.0 mm.
Width at anterior margin:	82.0 mm.
Width at midsection:	92.0 mm.
Width at posterior margin:	85.0 mm.

Remarks.—Mycterops ordinatus is one of the largest Arthropoda known. In Plate 38, figure 5, is shown a small fragment of the carapace which retains part of the marginal rim and the ornamentation of the type found on the posterior marginal side of the carapace. This fragment apparently is from the left side. It indicates an individual which may well have reached a length of the prosoma of six times the size of the lectotype, or approximately 30 cm. The fragment illustrated by Plate 38, figure 2, is slightly larger. It would, however, be hazardous to estimate the over-all length of this peculiar eurypterid inasmuch as no structure posterior to the first tergite is known. Nevertheless, it is readily apparent from the fragments known that *Mycterops* will rival the larger Pterygotids and Stylonurids in size.

The Belgian form, *Mycterops mathieui* Pruvost, is similar in many respects to *M. ordinatus.* However, specific differences are present. The compound eyes of *M. ordinatus* are located farther back on the carapace than those in *M. mathieui.* The former has a much wider prosoma than *M. mathieui* (6.1:10 as against 7.0:10). The first tergite of the latter is proportionately wider than in *M. ordinatus.*

Mycterops is so far known only from the Upper Carboniferous (Mid-Pennsylvanian in Pennsylvania and from the Westphalian of Belgium). The possibility of its presence in lower beds, or that of closely allied forms, is likely. Clarke & Ruedemann (1912, pl. 83, figs. 5–6) figured under the name *Eurypterus pristinus*, a carapace and a fragment of integument from the Ordovician Schenectady shale of New York. The carapace and integ-

ument may not represent the same species as stated by Clarke & Ruedemann. Our concern here is with the small fragment of integument (Pl. 83, fig. 6) which reveals ornamentation very much like that which characterizes *Mycterops*. The Chicago Natural History Museum has a small fragment of integument which is similar to the ornamentation of *Mycterops*. This specimen is from the Beartooth formation at the base of the Lower Devonian at Beartooth Butte, Wyoming. Both the Ordovician and Devonian fragments are too incomplete to extend definitely the range of the genus. Nevertheless, the possibility exists that the genus or family may occur in older beds.

Occurrence.—Associated with land plants, the eurypterid *Adelophthalmus mansfieldi* (C. E. Hall), fishes, and amphibians. The bed obviously is of fresh water origin. Darlington black shale, immediately below the Darlington coal, Allegheny formation, Pennsylvanian System, near Cannelton, Darlington township, Beaver County, Pennsylvania.

Superfamily STYLONURACEA Diener, 1924
WOODWARDOPTERIDAE Kjellesvig-Waering, new family

Stylonuracea of medium size; outer surface covered with coarse scales, tubercles and calculi; prosoma campanulate, with stylonuroid appendages increasing in size posteriorly. First and second tergites, greatly developed, the following normal in length.

This genus is named in honor of Henry Woodward whose many contributions to our knowledge of the Eurypterida are well known.

Type genus: *Woodwardopterus*, new genus.

WOODWARDOPTERUS Kjellevsvig-Waering, n. gen.

Woodwardoptidae of medium size, outer surface covered by coarse scales, tubercles and calculi, prosoma, companulate, eyes and ocelli unknown; prosomal appendages without spines but with supplementary lobes developed on anterior legs. First and second tergites greatly developed; opisthosoma, trilobate in posterior part; telson unknown.

Type species: *Eurypterus scabrosus* Woodward, 1887.

Stratigraphic range: Lower Carboniferous.

Distribution: Scotland.

Recognized species: *Woodwardopterus scabrosus* (Woodward).

Family HIBBERTOPTERIDAE Kjellesvig-Waering, new family

Stylonuracea of large size; exoskeleton with semilunar to long pointed triangular scales. Rounded highly arched prosoma with centrally located eyes and ocelli. Triangular processes between eyes. Coxae of posterior prosomal appendages without denticular processes. Ventral shield composed of two plates joined at the anterior with a suture. Metastoma, trapezoidal, cordate anteriorly, with median posterior suture and converging anteriorly. Male operculum unknown, female operculum with short club-shaped appendage and with anterior ovoid plate. Opisthosoma without any construction. Telson unknown.

The above family will embrace the morphological characteristics of the two genera discussed below, namely *Hibbertopterus* which is described as new and is considered the type genus of the family Hibbertopteridae, and *Campylocephalus*.

Genus HIBBERTOPTERUS Kjellesvig-Waering, n. gen.

Hibbertopteridae, with broad semi-circular prosoma and with centrally located arcuate eyes with narrow visual area; and surrounded by annular cuticular thickening.

This genus is named in honor of S. Hibbert who first recognized the eurypterid nature of the type species.

Type species: *Eurypterus scouleri* Hibbert.

Stratigraphic range: Lower Carboniferous, Upper Devonian(?).

Recognized species.

Hibbertopterus scouleri (Hibbert)
Hibbertopterus? stevensoni (Etheridge)
Hibbertopterus? hibernicus (Baily)

Distribution: Scotland and Ireland(?).

Genus CAMPYLOCEPHALUS Eichwald, 1860

Hibbertopteridae with subelliptical prosoma, narrow at base and broadest at mid-section; compound eyes; reniform, without annular cuticular thickening; and located in posterior half of prosoma.

Type species: *Campylocephalus oculatus* (Kutorga).

Stratigraphic range: Upper Carboniferous-Permian.

Recognized species.

Campylocephalus oculatus (Kutorga)
Campylocephalus? salmi (Stur)

Distribution: Urals, U.S.S.R., and Czechoslovakia(?).

Remarks.—The last two genera above differ in the shape of the prosoma, which in *Hibbertopterus* is very broad, wider than long, and semicircular in outline. *Campylocephalus* has a prosoma which is narrow, longer than broad, subelliptical in outline, and reaches its greatest width at midsection rather than at the base. Another important difference is in the shape and position of the compound eyes. In *Hibbertopterus* the visual area is almost annular, sicle or arcuate, with a long palpebral lobe, and surrounded by a distinct ring composed of thickened integument. In *Campylocephalus* the visual area is kidney shaped, without an appreciable palpebral lobe, and without the annular cuticular thickening. The position of the compound eyes also differs greatly.

In *Hibbertopterus* the eyes are nearly centrally located. Those of *Campylocephalus* are located in the posterior half of the prosoma, a feature found only in this genus and in *Melbournopterus* and *Tarsopterella* of the family Stylonuridae.

REFERENCES

CLARKE, J. M. & RUEDEMANN, R., 1912, The Eurypterida of New York: New York State Mus., Mem. 14, 439 p., 88 pls.

COPE, E. D., 1886, An interesting connecting genus of Chordata (*Mycterops*): Am. Natur., v. 20, p. 1027–1031.

——, 1888, The pineal eye in extinct vertebrates: Am. Natur., v. 22, p. 914–917, pls. 15–18.

EICHWALD, E. VON, 1860, Lethaea Rossica I, Stuttgart.

HIBBERT, S., 1836, On the fresh-water limestone of Burdiehouse in the neighbourhood of Edinburgh, belonging to the Carboniferous Group of rocks. With supplementary notes on other fresh-water limestones: Royal Soc. Edinburgh, Trans., v. 13, p. 169–282, pls. 5–12.

JORDAN, H. & MEYER, H. VON, 1854, Ueber die Crustaceen der Steinkohlenformation von Saarbrücken, Palaeontographica, v. 4, p. 1–15, 2 pls. (1856).

KJELLESVIG-WAERING, E. N., 1948, The Mazon Creek Eurypterid: A revision of the genus *Lepidoderma:* Illinois State Mus., Sci. Papers, v. 3, no. 4, 46 p., 8 pls.

KUTORGA, S., 1838, Beitrag zur Kenntniss der Organischen Ueberreste des Kupfersandsteins am Westlichen Abhange des Urals: St. Petersburg, p. 1–38.

LESLEY, J. P., 1889, A dictionary of the fossils of Pennsylvania: Second Pennsylvania Geol. Survey, Report P4, v. 1–3, 1283 p.

MILLER, S. A., 1877, The American Palaeozoic fossils: A catalogue of the genera and species, etc., 253 p., Cincinnati, Ohio.

PŘIBYL, ALOIS, 1953, on the Genus *Adelophthalmus* Jordan and Meyer, 1854 (Eurypterida) and its representatives in the Upper Carboniferous of Czechoslovakia: Rospravy II. třidy Ceské akad., v. 53, no. 2, 17 p., 2 pls.

PROVOST, P., 1925, Un Euryptéride nouveau du Terrain houiller de Charleroi: Ann. de la Soc. Géol. du Nord, v. 48, p. 143–151, pl. 1.

SALTER, J. W., 1863, On some species of *Eurypterus* and allied forms: Quart. Jour. Geol. Soc., London, v. 19, p. 81–87.

SCOULER, J., 1831, Description of a fossil Crustaceous animal: Cheek's Edinburgh Jour. Nat. Geogr. Sci., n. s., v. 3, no. 4, p. 352–354, pl. X.

STØRMER, L., 1951, A new Eurypterid from the Ordovician of Montgomeryshire, Wales: Geol. Mag., v. 88, p. 409–422.

——, 1955, Treatise on Invertebrate Paleontology, Part P, Arthropoda 2, Chelicerata with sections on Pycnogonida and Palaeoisopus, Part on Eurypterida, p. P23–P41.

VAN OYEN, F. H., 1956, Contribution à la connaissance du genre *Adelophthalmus* Jordan et Meyer, 1854. Mededelingen van de geol. Stichting: serie C-IV-3, no. 7, 98 p., 24 pls., Maastricht.

WATERSTON, C. D., 1957, The Scottish Carboniferous Eurypterida: Trans. Royal Soc. Edinburgh, v. 63, pt. 2, no. 12, p. 265–288, 4 pls.

WOODWARD, H., 1887, On a new species of *Eurypterus* from the Lower Carboniferous shales of Glencartholm, Eskdale, Scotland: Geol. Mag., v. 4, p. 481–484, pl. 13.

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CONODONTS OF THE ORDOVICIAN GALENA FORMATION

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ABSTRACT—Conodonts obtained from acid residues of the Galena Formation in Iowa and Minnesota are described. The long-standing question of the correlation of this unit still exists, but the new fauna recovered from the three members of the Galena provides additional criteria for age determination. The conodont fauna consists of 48 species which are referred to 26 genera. Three of these genera, *Coelocerodontus*, *Goniodontus*, and *Rhynchognathus*, are new. *Belodina* is proposed for species formerly assigned to *Belodus*. *Panderodus* is established for forms previously placed in *Paltodus*. Well preserved conodonts are abundant in the limestone facies of the Galena, whereas they are rare and poorly preserved in the dolomite facies of that formation. Conodonts from the lower Prosser represent a continuation of the underlying Decorah fauna and are very similar to the conodonts of the Kimmswick of northern Missouri and the lower Viola of Oklahoma. A probable late Mohawkian age for these strata is indicated. Faunal elements introduced in the upper Stewartville and Dubuque suggest an early Upper Ordovician age for these beds. Detailed correlation of the members of the Galena Formation with the standard Ordovician section in eastern United States cannot be accomplished at this time owing to incomplete knowledge of the faunas of the type Trenton and Cincinnatian.

INTRODUCTION

OCCURRENCE of conodonts in acid residues from the lower part of the Galena Formation of southeastern Minnesota was reported by Weiss (1955; 1957). The conodonts were not described, and they were not included in his faunal list. The present investigation is a study of the conodont fauna of the Galena Formation of northeastern Iowa.

European workers have recently reported on comprehensive studies of Ordovician conodont faunas obtained from acetic acid residues of samples from carbonate strata (Rhodes, 1953, 1955; Lindström, 1954). This method was used in work on the Galena. Preliminary sampling showed preservation of conodonts to be poor in dolomitic material but generally excellent in the more nearly pure limestones. Samples from shales were for the most part unproductive or yielded only fragmentary specimens. For these reasons, systematic sampling was conducted in exposures of the Galena in Winneshiek and Clayton counties where the magnesian content of the limestone is low. Although no complete sections of the Galena were found in this area, sampling from 11 partial exposures permitted collection of representative material from the entire formation. An additional exposure near Chatfield, Minnesota, was sampled to provide material typical of the Cummingsville Member of the Galena, a basal unit recognized in southeastern Minnesota but not differentiated in Iowa.

More than 7000 identifiable conodont specimens were recovered from the Galena Formation. These specimens have been referred to 48 species and 26 genera. Although suprageneric groupings of conodonts have been proposed, the writer is of the opinion that, owing to uncertainty regarding affinities and functions of parataxa, classification of these fossils above the level of genus is not warranted. Greatest abundance of conodonts was found in the Dubuque Member. Conodonts are somewhat less common in the uppermost beds of the Stewartville Member and in the Prosser Member. The lower 35–40 feet of the Stewartville in the area sampled is highly dolomitic and contains only a meager and poorly preserved conodont fauna. All of the specimens figured in this report are catalogued and deposited in the Department of Geology, State University of Iowa.

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STRATIGRAPHY

James Hall (*in* Foster & Whitney, 1851) applied the name "Galena limestone" to a sequence of gray lead-bearing carbonate strata which lies above those beds containing a characteristic "Trenton" fauna in southwestern Wisconsin, northwestern Illinois, and northeastern Iowa. Winchell & Ulrich (1897) in their classic study of the geology of southeastern Minnesota subdivided the Galena Limestone into four "beds," each characterized by a zonal fossil. Later Ulrich (1911a) used the name Prosser Limestone for those strata included in the *Clitambonites*, *Nematopora*, and *Fusispira* beds. In a subsequent publication, Ulrich (1911b, pl. 27) applied the name Stewartville Dolomite to the *Maclurea* bed. Both Prosser and Stewartville were apparently proposed as units of formational rank, but many subsequent authors have considered them to be members of the Galena Formation. Sardeson (1907) proposed the name Dubuque Formation for the thin carbonate strata with shaly partings, previously identified as the "*Triplecia* Bed," which occur above the "cap rock" at Dubuque, Iowa and included this unit in the Maquoketa Series. Kay (1935b) restricted the Dubuque to Bed 15 of the section at Dubuque, Iowa, as described by Calvin & Bain (1899) and correlated the exposures of this unit with the zone of *Oxoplecia* (*Triplecia*) *ulrichi* (Winchell & Schuchert) in southeastern Minnesota. The Dubuque is included in the Galena by Kay, whereas Stauffer & Thiel (1941) followed Sardeson in placing it in the Maquoketa. Weiss (1957) treated the Dubuque of southeastern Minnesota as a distinct formation between the Galena and Maquoketa. The Cummingsville Member was defined by Weiss (1955) for the argillaceous lower beds of the Galena in exposures near Cummingsville, Fillmore County, Minnesota. The Cummingsville Member cannot be differentiated in northeastern Iowa, but the shaly lower Prosser in the Decorah, Iowa, area is apparently equivalent.

The boundary between the Prosser and the underlying Ion Member of the Decorah Formation falls within a zone of transitional lithology at all localities at which these strata have been described in northeastern Iowa and southeastern Minnesota. In the area studied, the contact is in a zone of light greenish-gray shales alternating with thin-bedded or nodular limestones. Kay (1928) described a persistent faunal zone characterized by *Prasopora simulatrix* Ulrich at the top of the Ion. In this report the base of the Prosser is considered to be immediately above the *Prasopora* zone.

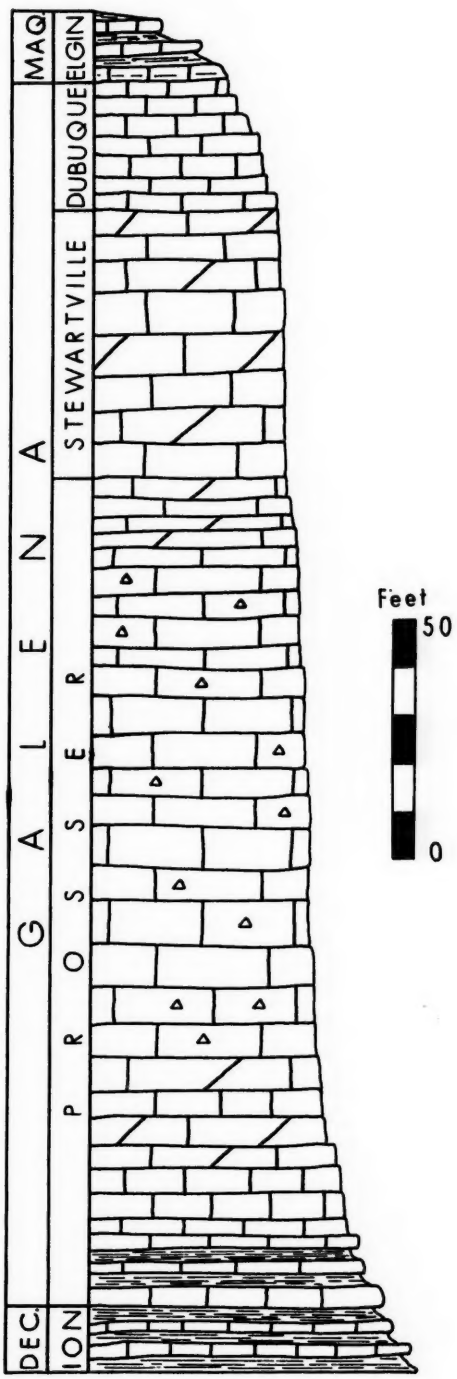
In the area covered by this study approximately the lower 50 feet of the Prosser consists of gray fine-grained argillaceous limestone with interbeds or partings of greenish-gray shale. The detrital content of the carbonate strata and frequency of shale beds and partings decreases upward, and this zone grades lithologically into the overlying beds. *Receptaculites oweni* (Hall) is abundant in the upper half of the shaly zone and constitutes the Lower *Receptaculites* Zone of authors. The strata above the shaly zone consist of light gray to light yellow-brown fine-grained limestone occurring in beds ranging from two to six feet in thickness. Occasional shale partings and thin clay layers, possibly metabentonite, up to an inch thick are present. Megafossils, principally brachiopods, corals, and bryozoans are abundant in much of the middle Prosser. Gray nodular chert is common throughout the Prosser above the shaly beds. The limestones of the upper 15–20 feet of the Prosser are increasingly magnesian toward the top of the member, and the unit grades into the overlying Stewartville Member.

Following Kay (1935b) the base of the Stewartville is considered to be indicated by the lowest appearance of *Maclurites* in the section. The Stewartville consists of massive beds, three to six feet thick, of fine-grained dolomitic limestone. Where more intensely weathered, the massive beds have split into thinner units ranging from three inches to a foot in thickness. A uniform characteristic of the upper beds of the Stewartville is the abundance of crinoid

columnals which are more resistant than the matrix and stand out in relief on weathered surfaces. Columnals are particularly prominent in the 10 feet of strata immediately underlying the Dubuque and serve to identify the upper Stewartville.

At the type section in Dubuque, Iowa, the Dubuque Member consists of light gray to buff thin-bedded dolomite with shale partings. As has been indicated by Kay (1935), the magnesian content of the Dubuque beds decreases northwestward along the outcrop belt from Elkader in Clayton County, Iowa. In the area around Decorah in central Winneshiek County, the Dubuque is composed of wavy irregular beds of gray-brown argillaceous limestone ranging in thickness from four to ten inches and alternating with thin gray shale beds or partings. The basal limestones contain crinoid columnals, although in lesser abundance than the underlying Stewartville beds. The base of the Dubuque Member is placed beneath the lowest shale bed in the section.

A generalized columnar section of the Galena Formation in the area of this report is shown in Text-figure 1.



TEXT-FIG. *1*—Generalized columnar section of the Galena Formation.

AGE OF THE GALENA

Winchell & Ulrich (1897) concluded that the Prosser and Stewartville of southeastern Minnesota are equivalent to the entire Trenton Group of New York and Canada. The overlying Ordovician strata, including the Dubuque and Maquoketa, were correlated with the Eden and possibly the Maysville at the type localities near Cincinnati, Ohio. Lower Prosser was correlated with the Hull of New York by Kay (1935), and the upper Prosser was considered to be equivalent to the Sherman Fall of northern Michigan. Cooper (1956) correlated the entire Prosser with the Sherman Fall owing to the appearance in the former of a brachiopod fauna including *Vellamo*, *Platystrophia*, and *Furcitella*. Both Kay and Cooper considered the Prosser to be equivalent to the Kimmswick of Missouri.

Foerste (1929b) and Kay (1935a; 1935b) recognized similarity of the faunas of the Stewartville and the Red River Formation of Manitoba. Considerable difference of opinion has been expressed by various authors regarding the age of the Red River

and its stratigraphic equivalents. The majority of the fossils present are believed indicative of Trenton age, but a portion of the fauna has affinities with forms from the younger Richmond. Foerste (1929a) noted that the bryozoans, brachiopods, and gastropods of the Red River have Mohawkian affinities, whereas the corals, and particularly the cephalopods, have Richmond affinities. He concluded the appearance of species having Richmond affinities is of greater significance than a high percentage of holdover Middle Ordovician forms, and therefore, accepted a Richmond age for the Red River fauna. Kirk (1925; 1930) believed these faunas indicated early Upper Ordovician rather than Richmond age. Miller et al. (1954) summarized previous reports dealing with the Red River fauna and described similar fossils from Baffin Island. The majority of the nautiloids from the Baffin Island locality are considered to indicate an Eden and/or Maysville age. An extensive coral fauna from Red River correlatives in western United States is believed by Duncan (1956) to suggest Cincinnatian age. Although direct faunal comparison cannot be made owing to scarcity of corals in the type Cincinnatian, Duncan expressed the opinion that the horn corals of the Red River equivalents display a degree of differentiation and complexity which seems unlikely to have developed by Middle Ordovician time. Fossils, primarily brachiopods and corals, obtained from the subsurface in the Williston Basin of eastern Montana were interpreted by Ross (1957) to indicate Cincinnatian age of the Red River and its correlatives. In comparing the nautiloids of the Red River with those of eastern North America, Flower (1957a; 1958) concluded that the former are indicative of late Trenton or early Cincinnatian age. Recently Flower (1957b; 1958) also suggested that the type late Trenton and Eden may be in part equivalent.

Kay (1935a) included the Dubuque in the Galena and, owing to comparable stratigraphic position and fauna, correlated it with the Collingwood of Northern Michigan to which a Trenton age was assigned. Absence of many typical Galena fossils in the Dubuque was noted by Stauffer & Thiel (1941) who assigned these beds to the Maquoketa. Twenhofel (*in* Twenhofel, et al., 1954) correlated the Stewartville-Dubuque sequence with the Red River and equivalent units and considered them to be of Richmond age. Following a study based chiefly on brachiopods, Weiss (1957) concluded that the fauna of the Dubuque of southeastern Minnesota, although intermediate between that of the Prosser-Stewartville sequence and that of the Maquoketa, is closer to typical Galena forms.

Agnew (1955), following extensive investigation of the Ordovician rocks in the subsurface of western and southern Iowa, recognized lithologic similarity between the upper Galena and Maquoketa in these areas. Owing to this lithologic continuity, he expressed belief that no significant break occurred during deposition of the Galena-Maquoketa sequence in Iowa. Agnew considered the Eden-Maysville interval to be represented in Iowa by upper Galena strata which do not contain a fauna characteristic of shale facies and, therefore, cannot be directly correlated with type Lower Cincinnatian. Gutstadt (1958) correlated rock units in subsurface between widely separated wells in Illinois, Indiana, Ohio, and Iowa. The rock units of the section at Cincinnati, Ohio, were considered to grade laterally into the beds of the Maquoketa Group in Indiana. The laterally continuous Upper Ordovician sequence thus defined was shown to be everywhere underlain by carbonate strata, including the Galena, to which Middle Ordovician age was assigned. Gutstadt (p. 542) concluded that equivalents of the Eden and Maysville may occur in the basal Maquoketa but not in the Galena. No faunal analysis was made however.

GALENA CONODONTS

Galena Conodont Localities.—Preliminary sampling indicated that conodonts are very poorly preserved or completely absent in the dolomitic facies of the Galena along the Mississippi River, whereas they are relatively abundant in the limestone facies of the Decorah area to the west. For this reason, detailed study was restricted to the limestone portion of the Galena outcrop belt extending northwest from the general vicinity of Elkader in Clayton County. The Galena conodont fauna studied during this investigation was collected from eleven locali-

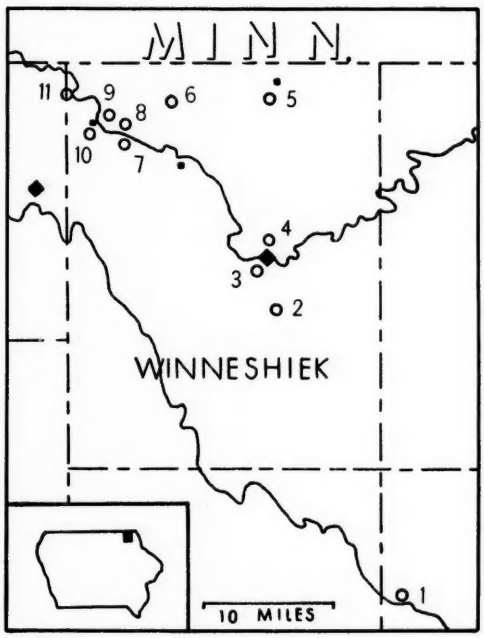
ties in Winneshiek and Clayton counties in northeastern Iowa. None of these exposures included the entire Galena Formation. Argillaceous lower Galena strata, typical of the Cummingsville Member of Weiss, were sampled at a single exposure near Chatfield, Olmsted County, Minnesota. Locations of the Iowa localities are indicated in Text-figure 2.

Locality 1.—Twenty-five miles southeast of Decorah, Iowa, the contact between the Dubuque and the overlying Maquoketa is exposed on the east side of county road K in northwestern Clayton County, Iowa (NW¼, sec. 21, T. 94 N., R. 6 W.). The Maquoketa at this locality consists of three inches of basal phosphatic clay, containing a sparse fauna of small sponges and molluscs, overlain by two feet of gray to brown shale. Seventeen feet of thin-bedded limestones of the Dubuque are exposed. Conodonts are abundant in all beds of the Dubuque at this locality. Preservation of the fauna is only fair, and the surfaces of most specimens are etched.

Locality 2.—The lower 11 feet of the Dubuque and the upper 19 feet of the Stewartville are exposed in an abandoned quarry along the right of way of the Chicago, Rock Island, and Pacific Railroad just north of the village of Nordness, Winneshiek County, Iowa (Center, sec. 10, T. 97 N., R. 8 W.). Well preserved conodonts are abundant in the Dubuque limestones at this locality. Stewartville conodonts are uncommon except in the upper crinoidal beds, and preservation ranges from good to fair.

Locality 3.—Twenty-seven feet of gray to buff, fine-grained limestone belonging to the middle part of the Prosser Member crop out in a weathered roadside exposure on the east side of U. S. Highway 52 at the south edge of Decorah, Iowa (SW¼, sec. 21, T. 98 N., R. 8 W.). Limestones from this exposure contain abundant conodonts. Samples from bentonitic clay partings were barren.

Locality 4.—Almost the entire Prosser is exposed in a series of roadcuts on alternate sides of county road L at the north edge of Decorah, Iowa (SE¼, sec. 9, T. 98 N., R. 8 W.). The contact with the underlying Decorah is exposed in the creek bed below the lowest roadcut. Twenty feet of mottled gray to buff dolomitic limestone beginning



TEXT-FIG. 2—Index map of Iowa showing collecting localities.

30 feet above the base of the member, and 25 feet of similar lithology at the top of the exposure, contain only a sparse and poorly preserved conodont fauna. The limestones of the remainder of this exposure yielded well preserved conodonts in moderate abundance. Shale samples from the basal part of the member proved to be barren or contained only a meager fauna.

Locality 5.—Twenty feet of basal Prosser is exposed in a small quarry one mile southwest of Hesper, Winneshiek County, Iowa (NW¼, sec. 22, T. 100 N., R. 8 W.). The contact with the Decorah is not exposed, but green Decorah shales crop out in the nearby creek bed. A sparse conodont fauna was recovered from material collected from the limestones at this exposure. Shale samples were unproductive.

Locality 6.—Thirty-eight feet of the Stewartville is exposed in a quarry three miles west of Burr Oak, Iowa (SE¼, sec. 20, T. 100 N., R. 9 W.). Occurrence of abundant *Receptaculites*, *Hormotoma*, and *Macluri*tes in the lower 10 feet of the quarry face suggests that the base of the exposure is approximately at the horizon of the Stewart-

ville-Prosser contact. Conodonts were recovered throughout the entire section exposed at this locality, but preservation was poor and all specimens had etched surfaces. Only a few long ranging species were represented.

Locality 7.—A complete Dubuque section and the upper Stewartville are exposed in the quarry at the fork in the road a mile and a half southeast of Kendallville, Iowa ($W\frac{1}{2}$, sec. 2, T. 99 N., R. 10 W.). The lower 20 feet of the Stewartville consists of massive beds of fine-grained blue-gray dolomitic limestone. The upper 10 feet of Stewartville is crinoidal and buff to gray in color. The Dubuque is 18.3 feet thick at this exposure. Owing to slumping in the thin shale and limestone beds of the overlying Elgin Member of the Maquoketa, the upper contact of the Galena is obscure. Conodonts are rare and poorly preserved in the massive lower beds of the Stewartville exposed in this quarry, whereas they are common in the crinoidal beds. An abundant conodont fauna was recovered from the Dubuque limestones, but the shale beds of that member yielded only a few broken specimens.

Locality 8.—A section on the east side of the county road along the western boundary of sec. 35, T. 100 N., R. 10 W., one and one half miles east of Kendallville, Iowa, contains the upper Stewartville, the entire Dubuque, and the basal Maquoketa. Detailed sampling of the Dubuque beds yielded an abundant and well preserved conodont fauna.

Locality 9.—The upper Stewartville beds are exposed in the quarry just north of the Upper Iowa River bridge at Kendallville, Iowa ($NW\frac{1}{4}$, sec. 33, T. 100 N., R. 10 W.). The upper 11 feet of strata in the quarry face consist of thin irregular beds of gray to buff dolomitic limestone containing crinoidal detritus. Massive blue-gray beds weathering to light buff make up the remaining 23 feet of the exposure. The Dubuque Member is not exposed in the quarry but thin limestones alternating with shales crop out to the north along State Highway 139 just above the level of the top of the quarry face. Conodonts are rare and poorly preserved in the lower massive beds, whereas they are common in the crinoidal strata.

Locality 10.—Seven feet of Dubuque and 18 feet of Stewartville are exposed in the quarry on the west side of State Highway 139 just south of Kendallville, Iowa ($SW\frac{1}{4}$, sec. 33, T. 100 N., R. 10 W.). The lower half of the Stewartville exposure is massive blue-gray limestone, whereas the upper half contains an abundance of crinoid columnals. The Dubuque limestones contain an abundant conodont fauna. Shales from that member are barren or yield rare fragmented specimens. Samples from the crinoidal Stewartville beds contained well preserved conodonts. Material from the lower Stewartville beds was sparse and poorly preserved.

Locality 11.—A roadside exposure along the boundary between Winneshiek and Howard counties, Iowa ($SE\frac{1}{4}$, sec. 18, T. 100 N., R. 10 W.), two miles south of the Minnesota border includes 34.5 feet of Stewartville and 17.5 feet of Dubuque. The Dubuque-Maquoketa contact is not exposed. Dubuque conodonts were abundant and well preserved in samples collected at this exposure. The conodonts in the Stewartville were rare and poorly preserved.

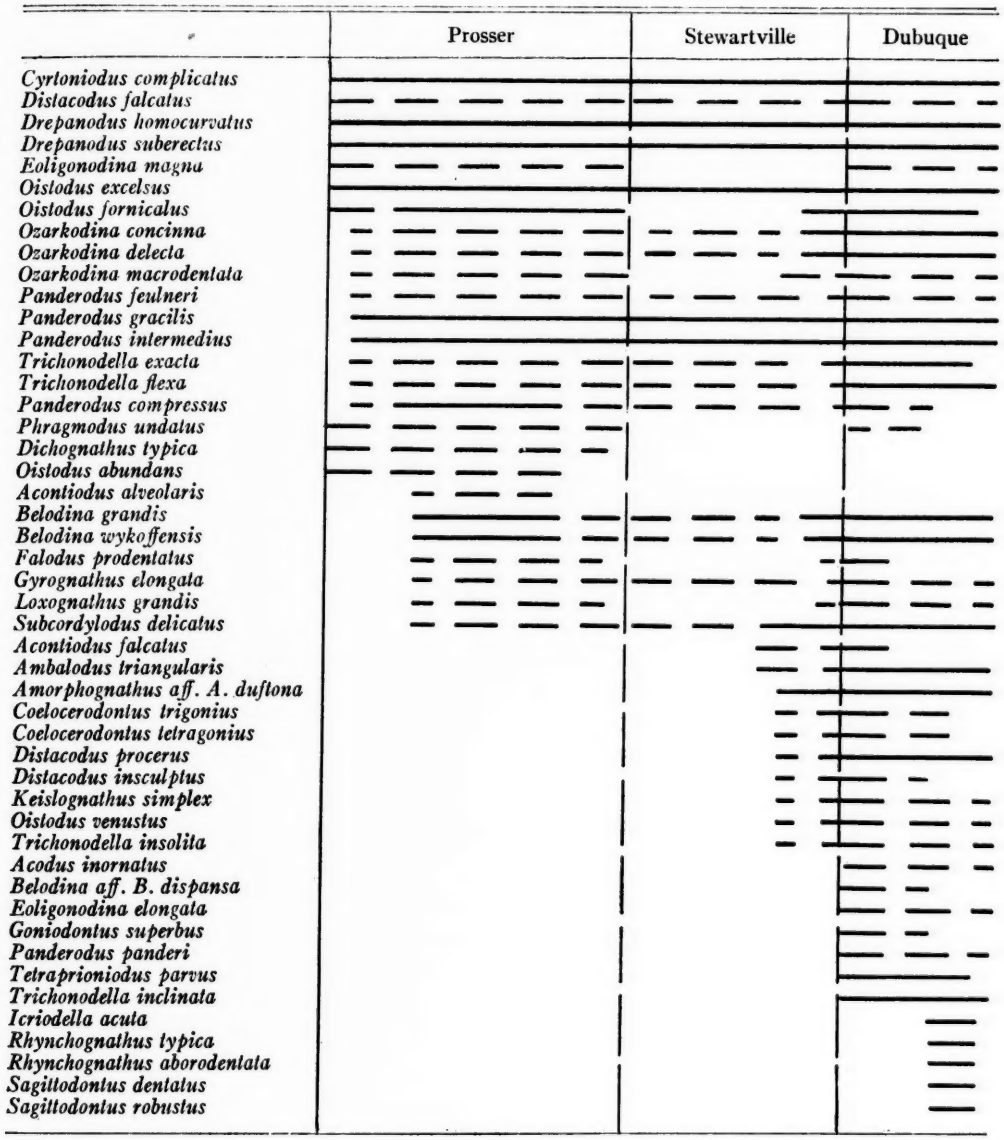
Locality 12.—A section of Galena strata comprising the basal part of the Cummingsville Member of Weiss was described along the south side of the county road ($NW\frac{1}{4}$, sec. 15, T. 105 N., R. 12 W.) five miles northwest of Chatfield, Olmsted County, Minnesota. Green Decorah shales containing "brassy" hematite oolites (Weiss, 1957) are exposed in a shallow ditch below road level. Actual contact between the Decorah and Galena is covered by slumped material. The Galena exposure consists of 32.5 feet of alternating gray fine-grained limestones and gray to greenish-gray shales. Conodonts are not common in the limestones, and only a small variety of forms occurs. The specimens recovered have etched surfaces. Samples of shales from this exposure were all barren.

Distribution of Conodonts within the Galena.—Galena conodonts are better preserved in the limestones of that formation than in the shales. Fragmentary specimens occur in the Dubuque shales. The shale beds in the lower Prosser are barren or contain a very meager fauna. Samples from shale partings in the cherty middle Prosser yielded small faunas having fair preservation. Forms re-

covered from shale samples are the same as those obtained from the enclosing limestone beds in both the Prosser and Dubuque members. Distribution of conodonts in the Galena is outlined in Table 1.

Conodonts are common in the limestones of the lower shaly zone of the Prosser. The greater part of the fauna in these beds consists of long ranging genera, and all but two species occur in all three members of the Galena. All of the genera recovered from this part of the section, except *Eoligonodina*, have been reported from the underlying Decorah. Nine of the 19 species are known from the Glenwood. Seven additional species are introduced in the cherty middle Prosser. Of these forms *Acontiodus alveolaris* is found throughout the remainder of the Galena. *Loxognathus* and *Falodus*, appearing for the first time in the middle Prosser, have

TABLE 1—DISTRIBUTION OF CONODONT SPECIES IN THE GALENA FORMATION



not been reported previously from the Iowa Ordovician. No additional forms appear in the upper Prosser or in the lower Stewartville; these beds are highly dolomitic, and the conodont fauna is meager and poorly preserved.

In addition to those forms which continue from the underlying beds, a new fauna containing genera which do not occur in the older formations in the Upper Mississippi Valley appears in the crinoidal zone at the top of the Stewartville. Nearly all of the forms in the new fauna are relatively rare in the Stewartville, but most of them become more abundant in the overlying Dubuque.

The Dubuque contains a more extensive conodont fauna than the other members of the formation. Preservation of the Dubuque fauna is excellent. Nearly all of the species which appear lower in the Galena are also present in the Dubuque and, in most cases, are found in greater abundance. Additional faunal elements not known from either Prosser or Stewartville appear in the base of the Dubuque. *Icriodella* and *Sagittodontus*, previously known only from Europe, together with the new genus *Rhynchognathus*, are restricted to the upper third of the Dubuque. Twenty of the 48 species of Galena conodonts also occur in the Maquoketa; nine of these have been reported only from the phosphatic basal unit of the Maquoketa.

STRATIGRAPHIC SIGNIFICANCE OF GALENA CONODONTS

Occurrences of the generic elements of the Galena conodont fauna in selected stratigraphic units in North America and Great Britain, together with those of some associated genera, are tabulated in Table 2. Stratigraphic units are grouped so that the older formations appear to the left in the chart.

The Galena fauna is intermediate between the conodonts of the older formations and those from the younger units listed. *Loxognathus*, *Falodus*, and *Acontiodus* are not known from strata younger than the Galena. Fourteen of the 26 genera in the Galena fauna occur in both younger and older formations. The majority of these long ranging genera are of little stratigraphic value even at species level. The remaining nine genera found in the Galena are known only from Galena or younger strata. Three of these genera, *Ambalodus*, *Keislognathus*, and *Coelocerodontus*, make their appearance in the crinoidal upper Stewartville and six others do not occur below the Dubuque. Two genera, *Coelocerodontus* and *Rhynchognathus*, are new and have not been described from other formations; *Goniodontus* is known from the Maquoketa.

The fauna of the Prosser is very similar to that reported from the Decorah of Minnesota by Stauffer (1935b) and undoubtedly represents a continuation of the latter. *Amorphognathus*, which occurs in the Decorah, was not recovered from the Prosser, but this genus is common in the upper Stewartville and abundant throughout the Dubuque. *Polycaulodus*, also absent in the Prosser but present in the Decorah, is abundant in the Plattin and apparently reached its greatest development there.

The fauna of the shaly basal Prosser is dominated by *Dichognathus* and *Phragmodus*. Both occur in a sparse basal Viola fauna from Oklahoma described by Branson & Mehl (1943). These genera constitute the major elements in a fauna obtained from limestones within the lower 50 feet of the Viola Formation, Pontotoc County, Oklahoma, which were kindly provided by Dr. Thomas W. Amsden for comparison. Occurrence of species of *Falodus*, *Loxognathus*, and *Subcordylodus* in the Viola material examined by the author emphasizes the similarity between this fauna and that of the Prosser. Kimmswick conodonts described by Strothmann and figured by Branson (1944) include 10 of the 16 genera known from the Prosser. *Chirognathus*, which constitutes a major portion of the Glenwood, Plattin, and Harding faunas, does not occur in the Galena or Decorah, and has not been reported from either the Viola or Kimmswick.

The *Receptaculites* and *Maclurites* faunas, which have been compared with those of the Red River Formation and its correlatives, occur near the base of the Stewartville but not in the crinoidal upper beds of that member. Conodonts are uncommon in these lower beds and, in most cases, poorly preserved. Those forms recovered from this part of the Galena have long stratigraphic ranges and are continuations of the more abundant Prosser fauna. For this reason the conodonts

TABLE 2—STRATIGRAPHIC DISTRIBUTION OF CONODONT GENERA

	Glenwood	Harding	Plattin	Kimmswick	Viola	Decorah	Prosser	Stewartville	Dubuque	Upper Bighorn	Maquoketa	Maravillas	Pen-Y-Garnedd	Gelli-Grin	Keisley	Richmond
Chirognathus	×	×	×													
Polycaulodus				×		×										
Ptiloconus			×	×	/	×										
Scyphiodus		×				×										
Loxognathus					×		×		×							
Falodus					×		×	×	×							
Acontiodus				×		×	×	×	×							
Cyrtoniodus		×				×	×	×	×	×	×					
Dichognathus	×		×	×	×	×	×				×					
Phragmodus			×	×	×	×	×		×		×	×				
Belodina			×	×		×	×	×		×	×	×				
Ozarkodina	×	×	×	×		×	×	×	×	×	×	×				
Acodus					×				×						×	
Drepanodus	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Oistodus	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×
Panderodus	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Trichonodella	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×
Distacodus	×	×			×	×	×	×	×		×		×		×	
Subcordylodus	×	×		×	×	×	×	×	×		×		×			
Amorphognathus		×				×		×	×	×	×	×	×	×	×	
Gyrognathus	×					×	×	×	×	×				×		
Eoligonodina							×	×	×	×			×	×	×	×
Ambalodus								×	×	×	×	×	×	×	×	
Coelocerodontus								×	×							
Keislognathus								×	×	/					×	
Tetraprioniodus									×	×					×	
Icriodella									×				×	×	×	
Sagittodontus									×				×	×		
Rhynchognathus									×							
Goniodontus									×		×					
Balognathus													×	×		
Holodontus														×		
Strachanognathus															×	
Aphelognathus															×	×
Zygognathus																×
Rhipidognathus																×

found in the lower Stewartville do not suggest a means of establishing the position of these beds within the standard Ordovician section of North America.

New elements in the Galena fauna which appear in the upper 10–15 feet of the Stewartville and in the lower Dubuque occur throughout the remainder of the formation as shown in Table 1. Rhodes (1955) has concluded that *Ambalodus* and *Amorphognathus* are characteristic of Upper Ordovician formations which are older than Richmond. Although *Amorphognathus* has also been described from the Harding and Decorah, Galena forms more closely resemble Upper Ordovician species described by Rhodes from Great Britain and by Glenister from the Maquoketa of Iowa. *Ambalodus* is not known from strata whose age has been demonstrated to be older than Upper Ordovician. Both *Tetraprioniodus* and *Keislognathus* were first reported from the Keisley Limestone of Westmorland whose fauna is considered by Rhodes (1955) to be somewhat older than that of the Richmond of Kentucky. *Tetraprioniodus* has also been found in the upper Bighorn by Stone (1958). The stratigraphic ranges of these latter two

genera have not been adequately determined as yet, but they may be restricted to Upper Ordovician strata.

The fauna of the upper third of the Dubuque includes *Sagittodontus*, *Icriodella*, and *Rhynchognathus* which are as yet unknown from other North American formations. *Sagittodontus* has been reported from the Upper Caradocian Gelli-grin and Pen-y-garnedd limestones by Rhodes (1953). Both of these formations as well as the Keisley Limestone contain *Icriodella*. *Balognathus* and *Holodontus* which occur in the Gelli-grin were not found in the Galena. *Panderodus*, which is abundant in the Maquoketa and Richmond as well as the Galena, is apparently uncommon in the Upper Ordovician of Great Britain (Rhodes, 1953, 1955). *Belodina*, abundant in the Galena, does not occur in either the Richmond or the British Caradocian faunas. Both *Zygognathus* and *Rhipidognathus* are thus far unknown from strata older than the Richmond formations of Kentucky and may therefore be diagnostic of uppermost Ordovician. *Aphelognathus*, a common form in the Richmond and rare in the Keisley Limestone, does not occur in either the Galena or Maquoketa; as has been emphasized by Rhodes (1955), however, it is similar and probably related to *Icriodella*, which is common in the uppermost Galena. Sweet & Miller (1958) reported the occurrence of conodonts in the type Eden. The fauna was not described in detail but was stated to be strikingly similar to those reported from the zone of *Pleurograptus linearis* [Gelli-grin and Pen-y-garnedd Limestones] in Wales (Rhodes, 1953). It may be possible to complete evaluation of the Stewartville and Dubuque faunas when the conodonts of such critical areas have been studied.

The fauna of the upper Stewartville and Dubuque is very close to that reported from the phosphatic member of the Maquoketa by Glenister. All of the genera reported

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EXPLANATION OF PLATE 39

FIG. *1*—*Panderodus gracilis* (Branson & Mehl), ×50, Stewartville Member, Locality 9, hypotype (10041).

2—*Panderodus feulneri* (Glenister), ×40, Stewartville Member, Locality 10, hypotype (10040).

3—*Panderodus intermedius* (Branson, Mehl & Branson), ×40, Stewartville Member, Locality 10, hypotype (10042).

4—*Panderodus compressus* (Branson & Mehl), ×60, Dubuque Member, Locality 10, hypotype (10039).

5—*Panderodus panderi* (Stauffer), ×50, Dubuque Member, Locality 8, hypotype (10043).

6,7—*Acontiodus falcatus* Ethington, n. sp. *6*, Lateral view; and *7*, posterior view, both ×60. Dubuque Member, Locality 7, holotype (10008).

8—*Distacodus procerus* Ethington, n. sp., ×60, Dubuque Member, Locality 7, holotype (10018).

9—*Distacodus falcatus* Stauffer, ×40, Prosser Member, Locality 3, hypotype (10019).

10—*Distacodus insculptus* (Branson & Mehl), ×40, Dubuque Member, Locality 7, hypotype (10020).

11—*Acodus inornatus* Ethington, n. sp., ×60, Dubuque Member, Locality 7, holotype (10006).

12—*Sagittodontus robustus* Rhodes, ×50, Dubuque Member, Locality 8, hypotype (10048).

13—*Sagittodontus dentatus* Ethington, n. sp., ×80, Dubuque Member, Locality 8, holotype (10047).

14—*Coelocerodontus trigonius* Ethington, n. sp., ×80, Stewartville Member, Locality 9, holotype (10014).

15—*Coelocerodontus tetragonius* Ethington, n. sp., ×80, Stewartville Member, Locality 7, holotype (10015).

16—*Drepanodus homocurvatus* Lindström, ×40, Dubuque Member, Locality 7, hypotype (10021).

17—*Drepanodus suberectus* (Branson & Mehl), ×60, Dubuque Member, Locality 7, hypotype (10022).

18—*Falodus prodentatus* (Graves & Ellison), ×75, Dubuque Member, Locality 10, hypotype (10025).

19—*Oistodus fornicalus* Stauffer, ×55, Dubuque Member, Locality 10, hypotype (10033).

20—*Oistodus excelsus* Stauffer, ×80, Dubuque Member, Locality 8, hypotype (10032).

21—*Oistodus abundans* Branson & Mehl, ×55, Prosser Member, Locality 4, hypotype (10031).

22—*Oistodus venustus* Stauffer, ×120, Stewartville Member, Locality 10, hypotype (10034).

23,24—*Acontiodus alveolaris* Stauffer. *23*, Lateral view; and *24*, posterior view, both ×60, Prosser Member, Locality 4, hypotype (10007).

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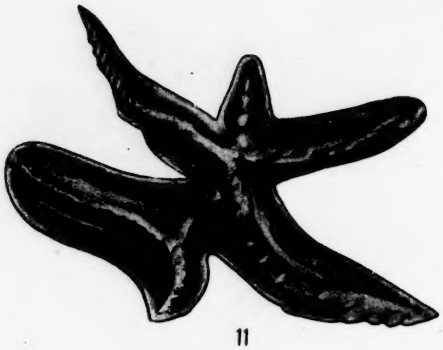
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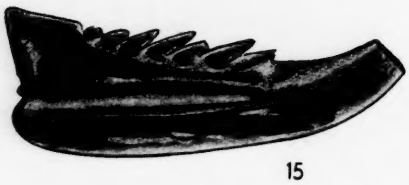
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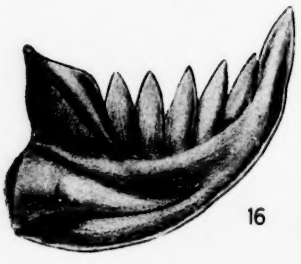
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from that unit except *Dichognathus* also occur in the Dubuque. Principal difference of the basal Maquoketa fauna from that of the uppermost Galena is the absence from the former of *Icriodella*, *Sagittodontus*, and *Rhynchognathus*. *Ambalodus* and *Amorphognathus* are characteristic of this phosphatic bed just as they are in the uppermost Galena. The conodonts of the succeeding members of the Maquoketa consist of forms with less stratigraphic significance.

Conodonts have not been described from the Ordovician of the Arctic regions of North America. A sparse fauna consisting of nondescript distacodids was recovered by the author from acetic acid residues of black limestones from the Cape Phillips Formation collected by Raymond Thorsteinsson on the southeastern part of Little Cornwallis Island (Sweet & Miller, 1958). The author has also obtained a more diverse conodont fauna from limestones collected in incidental fashion by John R. Rohner along the North Knife River in northern Manitoba.

In conclusion, the fauna of the lower and middle Prosser is a continuation of that of the underlying Decorah, is similar to the faunas of the Kimmswick of northern Missouri and the lower Viola of Oklahoma, and is probably late Mohawkian in age. Upper Prosser and lower Stewartville conodonts are long ranging forms having no value for detailed correlation. Faunal elements introduced in the upper Stewartville and lower Dubuque suggest an early Upper Ordovician age for these strata. Uppermost Dubuque beds contain distinctive genera previously known only from the Upper Caradocian of Great Britain. Genera diagnostic of the Richmond were not found in the Galena and are not known from the Maquoketa. The base of the Upper Ordovician in northeastern Iowa cannot be defined on the basis of conodonts owing to the absence of stratigraphically significant forms throughout the upper Prosser and much of the Stewartville. More nearly precise correlation of the upper Galena with strata of lower Cincinnatian age in North America and Europe must wait until the ranges of Upper Ordovician conodonts are more definitely established in critical areas.

SYSTEMATIC DESCRIPTIONS

Genus Acodus Pander, 1856.

Type species: *A. erectus* Pander, 1856.

Acodus was established to include simple curved conical conodonts having anterior and posterior keels and one carinate lateral face. Representatives of this genus have

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EXPLANATION OF PLATE 40

FIGS. *1,2*—*Goniodontus superbus* Ethington, n. sp. *1*, Antero-lateral view; and *2*, posterior view, both ×120. Dubuque Member, Locality 9, holotype (10026).

3,4—*Eoligonodina magna* Ethington, n. sp. *3*, Inner lateral view; and *4*, outer lateral view, both ×75, Dubuque Member, Locality 10, holotype (10024).

5—*Eoligonodina elongata* (Rhodes), ×120, Dubuque Member, Locality 8, hypotype (10023).

6—*Loxognathus grandis* Ethington, n. sp., ×85, Dubuque Member, Locality 10, holotype (10030)

7—*Cyrtoniodus complicatus* Stauffer, ×60, Dubuque Member, Locality 7, hypotype (10016).

8—*Tetraprioniodus parvus* Ethington, n. sp., ×100, Dubuque Member, Locality 7, holotype (10050).

9,10—*Keislognathus simplex* Ethington, n. sp. *9*, Inner lateral view; and *10*, outer antero-lateral view, both ×110, Dubuque Member, Locality 11, holotype (10029).

11—*Amorphognathus* aff. *A. duftona* Rhodes, ×40, Dubuque Member, Locality 11, figured reconstruction from three fragmentary hypotypes (10010).

12—*Ambalodus triangularis* Branson & Mehl, ×120, Dubuque Member, Locality 8, hypotype (10009).

13—*Gyrognathus elongata* Rhodes, ×85, Dubuque Member, Locality 11, hypotype (10027).

14—*Belodina grandis* (Stauffer), ×60, Dubuque Member, Locality 10, hypotype (10012).

15—*Belodina* aff. *B. dispensa* (Glenister), ×120, Dubuque Member, Locality 8, hypotype (10011).

16—*Belodina wykoffensis* (Stauffer), ×60, Stewartville Member, Locality 10, hypotype (10013).

17—*Dichognathus typica* Branson & Mehl, ×60, Prosser Member, Locality 12, hypotype (10017).

been described from strata ranging in age from Lower Ordovician to Middle Silurian. The two questionable Pennsylvanian species illustrated by Gunnell (1931, pl. 29, figs. 1,2) from the Fort Scott Formation of Missouri are probably fish teeth. Ordovician forms have been figured from the Oneota Formation of Iowa, the Jefferson City Formation of Missouri, the Marathon and Fort Peña Formations of West Texas, the Keisley Limestone of northern England, the rocks along Morroch Bay in southern Scotland, the Glaukonitsand of Russia, and from south-central Sweden.

ACODUS INORNATUS Ethington, n. sp.
Pl. 39, fig. 11

Simple cone whose base is slightly flared laterally and expanded in an antero-posterior direction. The base of the cone is excavated by a symmetrical, conical basal cavity whose apex extends upward to the point of maximum curvature of the tooth. The unit is continuously curved throughout its length with greatest curvature just above the expanded base. Anterior and posterior edges of the denticle are sharp, becoming strongly keeled toward the base. Both lateral faces are convex. Convexity of one face is interrupted by a prominent longitudinal groove, opening posteriorly, whose outer wall forms a low lateral, posteriorly directed carina. Basally the groove is located posterior to the midline of the tooth and distally becomes asymptotic to the posterior edge. Both groove and carina are more strongly developed toward the base.

Occurrence.—The species was recovered from the Dubuque at all localities where this member was sampled. Although these forms occur throughout the Dubuque, they are not common in any bed within that member. Specimens were recovered from Locs. 1, 2, 7, 8, 10, 11.

Repository.—Figured holotype, S.U.I., 10006.

Genus ACONTIODUS Pander, 1856.
Type species: *A. latus* Pander, 1856.

Pander proposed the name *Acontiodus* for three specific forms with the stated intention of separating them into several genera at a later date. This procedure was never accomplished. The principal common feature of these original species is the development of a relatively broad concave posterior face which may bear a central longitudinal carina or keel. Lateral faces intersect in an acute angle to form a keel along the rounded anterior edge of the tooth or a convex anterior face is present. The anterior or lateral faces intersect the posterior face to form strong posterior lateral costae. Pander's figure of the type species (1856, Pl. 2, fig. 1b) indicates the presence of a moderately deep, conical basal cavity.

Forms referred to this genus have been described from rocks whose age ranges from Lower to Middle Ordovician. In addition to the three Baltic species, congeneric forms have been figured from the Kimmswick Formation of Missouri, the Oneota, Shakopee, and Spechts Ferry of the Upper Mississippi Valley, and the Woods Hollow and Fort Peña of West Texas.

A single species from the basal Bighorn Formation in the Bighorn Mountains, Wyoming (Amsden & Miller, 1942, p. 303, fig. 2a) does not show a concave posterior face and probably should be assigned to another genus. Laterally compressed forms such as *Acontiodus arcuatus*, *A. reclinatus*, *A. rectus*, and *A. rectus* var. *sulcatus*, proposed by Lindström (1954) for forms from the Lower Ordovician of south-central Sweden, lack a posterior face. It may be preferable to refer these species to *Distacodus*.

ACONTIODUS ALVEOLARIS Stauffer
Pl. 39, figs. 23,24

Acontiodus alveolaris STAUFFER, 1935b, Jour. Paleontology, v. 9, p. 601–602, pl. 74, fig. 44; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 62.

Remarks.—Prosser material assigned to this species closely agrees with that figured by Stauffer from the Decorah of Minnesota.

Occurrence.—This species was recovered only from a single sample taken 70 feet above the base of the Prosser in the road cut north of Decorah (Loc. 4).

Repository.—Figured hypotype, S.U.I., 10007.

ACONTIODUS FALCATUS Ethington, n. sp.
Pl. 39, figs. 6,7

Simple sharply recurved conical teeth having marked lateral expansion of the base.

Greatest curvature of the tooth is at about one-third height above base with distal portion nearly at right angle to the proximal third and roughly parallel to the plane of the base. Anterior face convex in cross section, becoming considerably broader toward base. Lateral edges of the denticle are sharp, forming prominent keels which become progressively narrower above mid-length. Posterior face is broadly concave below mid-height with a wide sharp central carina extending from just above the base to the tip of the tooth. Distal cross section of the unit is lachryform with sharp posterior edge. Basal outline is fusiform. The base of the tooth is deeply excavated by sharp conical basal cavity whose tip penetrates to the point of maximum curvature.

Remarks.—This species seems to be close to *Acontiodus iowensis* Furnish and the type species, *A. latus* Pander. It is more sharply curved and has a deeper basal cavity than either of these forms. The posterior carina is more prominent than that of *A. latus* and sharp rather than indented as in *A. iowensis.*

Occurrence.—This form is rare in the basal Dubuque and in the uppermost Stewartville. It was found in the Stewartville at Loc. 9, and it is present in the Dubuque at Locs. 1, 2, 7, 8, 10.

Repository.—Figured holotype, S.U.I., 10008.

Genus AMBALODUS Branson & Mehl, 1933.
Type species: *A. triangularis* Branson & Mehl, 1933.

This genus was proposed for aborally excavated platform-like dental units having a concave oral surface. A large cusp is located near the center of a parapet-like row of closely crowded or fused denticles along the convex margin. An outer lateral process of varying length bears one or more small denticles. Branson & Mehl (1944) included *Ambalodus* among the Neurodontiformes. Rhodes (1954) found no trace of fibrous structure in British specimens and X-ray photographs revealed no difference from lamellar conodonts. In a subsequent publication, Rhodes & Wingard (1957) suggested that *Ambalodus* belongs among the lamellar conodonts rather than the fibrous forms.

In Europe *Ambalodus* is known from stratigraphic units ranging in age from Lower to Upper Ordovician. In addition to *A triangularis*, Rhodes (1953) described four species from the Middle and Upper Ordovician of Wales. Lindström (1954) described a single specimen on which he based a new species from the Lower Ordovician of Sweden. Representatives of this genus in North America are known from the Maravillas of West Texas, the Bighorn of the Bighorn Mountains, the Maquoketa of the Upper Mississippi Valley, and the Thebes Sandstone of Missouri.

AMBALODUS TRIANGULARIS Branson & Mehl
Pl. 40, fig. 12

Ambalodus triangularis BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 127–128, pl. 10, figs. 35–37; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 62; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 280, pl. 20, figs. 28–31; RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 122–123; pl. 7, figs. 9–14; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 722, pl. 88, figs. 20, 21.

Remarks.—Specimens of this form conform closely to Glenister's description of material from the phosphatic member of the Maquoketa. The outer lateral bar has been broken on most specimens but, where present, bears a single slender denticle. A wide range in sizes occurs, presumably owing to the presence of various growth stages. No changes in form with different stages of growth were noted.

Occurrence.—This species is abundant in the lower half of the Dubuque and common in the upper half (Locs. 1, 2, 7, 8, 10, 11). Rare specimens were found in the uppermost Stewartville (Locs. 2, 7, 9).

Repository.—Figured hypotype, S.U.I., 10009.

Genus AMORPHOGNATHUS Branson & Mehl, 1933.
Type species: *A. ordovicica* Branson & Mehl, 1933.

Amorphognathus was established by Branson & Mehl on the basis of incomplete specimens from the Thebes Sandstone of Missouri. The genus is characterized by platform-like lobes, radiating from a palmate central area, bearing median ridges crowned with low closely-crowded or nodose denticles. Differences in number and configuration of lobes and variations in denticulation

serve to distinguish species. A species recovered by the author from limestones of the McGregor Member of the Platteville Formation at Guttenberg, Iowa, differs from typical *Amorphognathus* in having two of its six rays represented by deep denticulate blades rather than lobate platforms. Ellison (1946) and Branson & Mehl (1944) considered *Polyplacognathus*, described by Stauffer from the Decorah of Minnesota, to be a junior synonym of *Amorphognathus*.

Like *Ambalodus* this genus was placed among the fibrous conodonts by Branson & Mehl (1944). Recent studies by Rhodes (1954) indicated the absence of fibrous structure and apparent close relationship to the Conodontiformes.

The genus is known from British and North American strata and ranges from Middle to Upper Ordovician in age. In the United States, species of *Amorphognathus* have been figured from the Decorah and Maquoketa of Iowa and Minnesota, the Kimmswick of Missouri, the Maravillas of West Texas, and the Harding of Colorado. Congeneric forms are known from the Bighorn Formation in the Bighorn Mountains, Wyoming, and from the Platteville of northeastern Iowa.

Owing to the relative fragility of these complex conodonts, complete specimens are rare. Eight species have been described. Examination of the types of *Amorthognathus tridigitata* and *A. adunca* Glenister suggests that these forms are based on fragmentary specimens and probably belong in *A. complicata* Rhodes.

AMORPHOGNATHUS aff. A. DUFTONA Rhodes
Pl. 40, fig. 11

?Amorphognathus duftonus RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 123–124, pl. 9, figs. 1,3,5,8.

Complex platform dental units having six distinct rays radiating from a central palm. The oral surface of each unit bears a median ridge crowned with nodose or fused denticles. A low parapet around the periphery of the entire unit produces concave oral surfaces of the rays. The anterior ray is long and slender, the median ridge occupying the major part of the oral surface, whereas the posterior ray is broad and lanceolate. The median ridges of the anterior and posterior rays are continued across the central area to form a single sinuous central ridge. Denticles of the anterior ray progressively increase in height posteriorly. The lobate outer rays branch laterally from the central area and are directed anteriorly and posteriorly. A common sinuous median denticulated ridge connects the tips of the two rays. A short connecting ridge extends from the midpoint of the outer ridge to the central ridge on the palm. Two distinct interior rays arise from the central area. The anterior inner ray is short and narrow with a high median ridge. The linguiform posterior inner ray is long and narrow. Aboral surface of the unit is somewhat arched and excavated by a large basal cavity which is continuous beneath all of the rays.

Remarks.—No complete specimens of this form were recovered. The relatively narrow rays are fragile and tend to develop transverse breaks proximal to the central area. Fragments of individual rays are common. The accompanying illustration of this form is a reconstruction based on three specimens, of which the most nearly complete lacked a portion of the posterior outer ray and the entire anterior inner ray.

The type species of *Amorphognathus* from the Thebes Sandstone of Missouri has five rays. Forms having six rays are known from the Harding of Colorado, the Kimmswick of Missouri, the Decorah of Minnesota, the Platteville of Iowa, and the Keisley Limestone of northern England. The Galena specimens differ from *A. ramosa* (Stauffer) in having two distinct inner rays whereas the latter has a bifid inner lateral ray.

The posterior ray of *Amorthognathus duftona* Rhodes is not present on the types of that species and its shape is not known. The arrangement of the other five rays of *A. duftona* compares favorably with that of the Iowa material. The shapes of the corresponding rays vary slightly between the two forms but the denticulation is similar.

Occurrence.—*Amorphognathus* is common throughout the entire Dubuque Member but is most abundant in the basal beds (Locs, 1, 2, 7, 8, 10, 11). Although no complete specimens were obtained from the Stewartville, the massive, crinoidal upper beds of the unit contain scattered fragments of rays which cannot be distinguished from

those in the Dubuque (Locs. 2, 7, 9, 10).

Repository.—Figured hypotypes, S.U.I., 10010.

Genus BELODINA Ethington, n. gen.
Type species: *Belodus grandis* Stauffer, 1935.

Conodonts referred to this genus are complex dental units having an anteriorly directed horizontal cusp whose distal portion shows marked oral curvature. Lateral faces of the cusp may be smooth or carinate and are generally unequally developed so that the unit is longitudinally asymmetrical. The oral edge of the cusp bears a series of prominent laterally compressed denticles which may penetrate well into the cusp. Anterior and posterior edges of the denticles are fused throughout the greater part of their length. The base of the cusp, arbitrarily considered to be posterior in position, is expanded orally to form a prominent "heel" posterior to the first oral denticle. Two conical basal cavities extend anteriorly into the cusp from the base. The lower cavity is slender and penetrates more deeply into the cusp; it tapers distally to form a thread-like extension which curves orally parallel to the axis of the cusp. The upper cavity is laterally compressed and usually penetrates into the cusp as far as the base of the most posterior of the oral denticles.

Remarks.—*Belodina* is proposed for those species, formerly assigned to *Belodus*, which bear a relatively small number of blade-like, crowded, or fused denticles and whose cusp is deeply excavated. The base of *Belodina* is expanded orally to form a prominent "heel" posterior to the denticles.

Although the nature of the basal cavity was not considered in Pander's generic diagnosis of *Belodus*, his illustration (1856, pl. 3, fig. 8) showing the internal structure of the type species, *B. gracilis*, indicates a single conical basal cavity occupying the proximal third of the cusp. Branson & Mehl (1933) revised the generic description of *Belodus* on the basis of Ordovician specimens from Missouri which have deep conical excavations. Stauffer (1935b) described forms having similar external morphology from the Decorah of Minnesota but having two distinct conical cavities in each specimen. Several of the North American species assigned to *Belodus* are intermediate between forms with a single cavity and those having two cavities. Such forms have a single deep cavity which tends to be bifid distally. This character is not uniformly developed in these species, however, and is, therefore, not of fundamental importance. Intermediate species include *B. profundus* from the upper Bighorn in the Bighorn Mountains, Wyoming, and *B. ornatus* from the Maquoketa of Iowa. Both of these forms were first reported by Branson & Mehl from the Thebes Sandstone of Missouri, and the original descriptions do not clearly indicate the shape of the basal excavation in the type specimens of either. The types of *B. dispansus* Glenister from the Maquoketa of Iowa have basal cavities which are distinctly divided distally into small upper- and larger lower cones.

Belodus gracilis Pander bears widely spaced, peg-like denticles whereas all of the North American species except *B. lineatus* Stauffer have closely crowded or fused denticles. The keyhole-shaped basal outline of such forms and deep basal excavation of *Belodus* are suggestive of *Panderodus*, n. gen. [= *Paltodus* of authors].

Stauffer (1940) described two species, *Belodina devonicus* and *B. triangularis*, from a clay above the Cedar Valley Limestone near Austin, Minnesota. Owing to the presence at this locality of an admixture of definite Ordovician forms in a dominantly Devonian fauna, these species have been considered by association to be of Ordovician age (Fay, 1952). Rhodes & Dinely (1957) reported finding the same forms in the Devonian of Devonshire. They also believe these species represent Ordovician forms incorporated in Devonian strata. The author has recovered a closely related species in an Upper Devonian fauna from a clay lying on the surface of the Cedar Valley Limestone in Johnson County, Iowa. There is no reason to assume that the Iowa specimens represent reworked elements of an older fauna included in the Devonian. It therefore seems probable that these forms are of Devonian age rather than Ordovician as has been previously believed. However, denticulation of these forms differs markedly from that of other described species of *Belodus*, and, therefore, they may represent a distinct genus. *Belodella*, n. gen., is hereby proposed for

such forms with *B. devonicus* Stauffer, 1940, as type species.

Of the other species of *Belodus* proposed since Pander's definition of the genus, only *B. lineatus* closely resembles the type species in external form. The remaining species appear very close to *Belodina*. Restudy of the types may reveal that the basal cavities in these forms also conform to *Belodina*.

Belodina appears to range in age from Middle to Upper Ordovician. Species belonging in this genus are known from the upper Bighorn of Wyoming and from the Decorah, Galena, and Maquoketa of the Upper Mississippi Valley. Similar forms have not been reported from Europe.

Belodina aff. B. dispansa (Glenister)
Pl. 40, fig. 15

?Belodus dispansis Glenister, 1957, Jour. Paleontology, v. 31, p. 729–730, pl. 88, figs. 14,15.

Two nearly complete specimens resemble Glenister's types in having posteriorly inclined, closely crowded denticles occupying half of the oral edge of the cusp. The Dubuque specimens have only slight oral curvature of the cusp; the anterior undenticulated portion of the cusp curves gently inward. A low median ridge extends the entire length of each lateral face of the cusp. Transverse section of the denticulated portion of cusp is narrow at the oral edge, widens gradually toward the middle, then tapers to the narrow aboral edge. A deep sharp-pointed slender conical basal cavity, extends anteriorly to a point beyond the most anterior denticle. The types from the Maquoketa are nearly twice as large as the specimens from the Dubuque. Longitudinal striations of the lateral faces which characterize the type specimens are not observed on the Galena forms.

Remarks.—Two specimens from the Dubuque are compared with *B. dispansa* primarily on the similarity of denticulation. Differences in cross section, curvature, and size between Dubuque and Maquoketa forms may be the result of differences in growth stage of the organisms. Apparent absence of surface striations on the Dubuque specimens may be due to their much smaller size.

Occurrence.—Two specimens were recovered from the basal beds of the Dubuque in Localities 7 and 8.

Repository.—Figured hypotype, S.U.I., 10011.

Belodina grandis (Stauffer)
Pl. 40, fig. 14

Belodus grandis Stauffer, 1935b, Jour. Paleontology, v. 9, p. 603–604, pl. 72, figs. 46,47,49, 53,54,57; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 67.

Remarks.—Specimens from the Galena Formation agree closely with Stauffer's description and figures. Dubuque and upper Stewartville forms have four to six denticles with five the most common number. Representatives of the species from the Prosser bear six or seven denticles. Because the specimens from these units are alike in all other respects, this variation in denticulation is not considered sufficiently significant to warrant assignment of the younger forms to a different species. Lateral faces of the basal cone bear fine longitudinal striations which intersect the aboral edge in an acute angle.

Occurrence.—*Belodina grandis* is common throughout the Dubuque at all localities but rare in the upper Stewartville beds (Locs. 2, 7). This species was recovered from the Prosser in both of the road cut localities at Decorah (Locs. 3, 4).

Repository.—Figured hypotype, S.U.I., 10012.

Belodina wykoffensis (Stauffer)
Pl. 40, fig. 16

Belodus wykoffensis Stauffer, 1935b, Jour. Paleontology, v. 9, p. 604, pl. 72, figs. 51,52,55, 58,59; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 67.

Remarks.—Representatives of this species from the Galena conform closely to Stauffer's illustrations of material from the Decorah of Minnesota. Internal lateral face of unit is gently and uniformly convex whereas the external face has a prominent shelf-like ridge extending anteriorly from the middle of the base to the tip of the cusp and inclosing the lower part of the denticles. The denticles are set deeply into the oral edge of the cusp. Aboral edge of the unit is blunt. Larger specimens carry fine longitudinal striae extending anteriorly from the base along the lateral faces and intersecting the aboral margin. Prosser forms bear 5–6 denticles; Dubuque and upper Stewartville

specimens bear 4–5 denticles. Preservation is generally excellent although the tip of the cusp has been broken on the majority of specimens. The figured specimen shows regeneration of the tip of the cusp.

Occurrence.—*Belodina wykoffensis* was recovered from Prosser material from the north and south Decorah roadcuts. The species is common in the upper Stewartville (Locs. 2, 6, 7, 9, 10) and abundant in the Dubuque (Locs. 1, 2, 7, 8, 10, 11).

Repository.—Figured hypotype, S.U.I., 10013.

Genus COELOCERODONTUS
Ethington, n. gen.
Type species: *C. trigonius*

The genus *Coelocerodontus* is proposed for simple hollow horn-shaped cones. Lateral walls are thin and enclose a central cavity which extends to the tip of the tooth. Edges of the tooth are keeled. Species are identified on the basis of the shape of the cross section.

Remarks.—These forms do not appear to be close to any of the other distacodid genera. They resemble *Panderodus*, n. gen. [= *Paltodus* of authors] and *Sagittodontus* in having a deep basal cavity. That of *Panderodus*, however, rarely penetrates completely to the tip of the tooth. The thin walls of *Coelocerodontus* are unique. All of the other deeply excavated simple cones have thick walls enclosing the central cavity.

COELOCERODONTUS TRIGONIUS
Ethington, n. sp.
Pl. 39, fig. 14

Simple hollow teeth whose cross section is nearly an equilateral triangle. The anterior face is convex whereas the postero-lateral faces are either concave or planar. The tooth is curved throughout its length with curvature increasing toward the tip. Posterior and lateral edges of the tooth are prominently keeled from base to tip. Walls are thin sheaths enclosing a deep cavity which extends throughout the unit. Basal portion of the tooth tends to flare slightly.

Occurrence.—This form occurs throughout the Dubuque (Locs. 1, 2, 7, 8, 10, 11) but is most abundant in the lower five feet of that formation. Upper Stewartville specimens are rare (Locs. 2, 7, 9).

Repository.—Figured holotype, S.U.I, 10014.

COELOCERODONTUS TETRAGONIUS
Ethington, n. sp.
Pl. 39, fig. 15

Simple smoothly curved hollow teeth with quadrate cross sections. Basal portion of unit flares slightly. Prominent keels extend from the base to the tip of the tooth along the angles between the four faces. In mature specimens, the distal portion of the tooth may be somewhat twisted. The walls of the unit are thin, sheathing a basal cavity which penetrates to the tip.

Remarks.—This form differs from *C. trigonius* in having a square rather than triangular cross section.

Occurrence.—Specimens of this form were recovered from the Dubuque (Locs. 1, 2, 10, 11) and upper Stewartville (Locs. 7, 9).

Repository.—Figured holotype, S.U.I., 10015.

Genus CYRTONIODUS Stauffer, 1935.
Type species: *C. complicatus* Stauffer, 1935.

Rhodes (1953) noted the similarity between the type species, *Cyrtoniodus complicatus*, and *Prioniodus? flexuosus* Branson & Mehl. Owing to the redefinition of the latter genus by Lindström (1954), Rhodes and Müller (1956) erected the new taxon *Neoprioniodus* for those species excluded from *Prioniodus*, *P.? flexuosus* among them. *Cyrtoniodus* is close to *Neoprioniodus* in outline and configuration of the dental unit. A basal excavation is only slightly developed or absent in *Neoprioniodus*, (Rhodes & Müller, 1956). By contrast, *Cyrtoniodus* has a deep groove beneath the posterior bar which merges anteriorly with a conical cavity beneath the cusp. The latter produces a pronounced flaring of the inner lateral walls of the unit at the juncture between the weak anticusp and the posterior bar and a moderate convexity of the outer wall in the same position. The basal outline of *Prioniodus? flexosus* is typical of *Cyrtoniodus*, and it appears to belong here rather than in *Neoprioniodus*.

Five species have been proposed in *Cyrtoniodus* of which two, *C.? delicatus* and *C. worthingtonensis* from the Olentangy

Shale of Ontario and central Ohio, should probably be included in *Neoprioniodus*. *Cyrtoniodus* is thus restricted to Middle and Upper Ordovician rocks of North America and Great Britain.

CYRTONIODUS COMPLICATUS Stauffer
Pl. 40, fig. 7

Cyrtoniodus complicatus STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 140,158, pl. 11, figs. 44,46,48–51; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 85; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 302, pl. 22, figs. 193–196; SWEET, 1955, Jour. Paleontology, v. 29, p. 254, pl. 28, fig. 3; GLENISTER, 1957, ibid., v. 31, p. 732, pl. 88, fig. 16.

Remarks.—Rhodes (1953, p. 302) expanded Stauffer's original description of the species on the basis of material from the Llandeilo Limestone of South Wales. The specimens from the Galena agree in detail with the British forms and those described by Glenister from the Maquoketa of Iowa.

Occurrence.—This species occurs throughout the Galena Formation. It is common in the Prosser (Locs. 3, 4, 5, 12) and upper Stewartville (Locs. 2, 7, 10) and abundant in the Dubuque (Locs. 1, 2, 7, 8, 10, 11).

Repository.—Figured hypotype, S.U.I., 10016.

Genus DICHOGNATHUS Branson & Mehl, 1933.
Type species: *D. prima* Branson & Mehl, 1933.

Branson & Mehl erected the genus for arched blade-like conodonts having a marked offset of the outer lateral face beneath the apical denticle. This genus is widespread in its occurrence in Middle and Upper Ordovician rocks of central and western United States but has not as yet been reported from Europe. The type species was described from the Harding Formation of Colorado. Congeneric forms have been reported from the Joachim, Plattin, and Kimmswick of Missouri, the Glenwood, Decorah, and Maquoketa of Iowa, the Viola of Oklahoma, and the Fort Peña of West Texas.

DICHOGNATHUS TYPICA Branson & Mehl
Pl. 40, fig. 17

Dichognathus typica BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 113, pl. 9, figs. 27–29; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 86; GLENISTER, 1957, Jour. Paleontology, v.31, p. 735, pl. 8, figs. 4,6; AMSDEN, 1957, Oklahoma Geol. Survey, Circ. 43, p. 35.

Remarks.—Branson & Mehl (1933) stated that *Dichognathus* is abundantly represented by a series of gradational forms in the Plattin Formation of Missouri. These authors established *D. typica* as one of several species to record what they considered definite "trends" in this series. Specimens of *Dichognathus* from the Galena show slight variations in the number of denticles on both the anterior and posterior halves of the blade. The variations are considered to be within the limits of *D. typica*, and the Galena forms are placed in this species. Many of the specimens are broken and either the anterior or posterior half of the blade is missing. Galena forms compare favorably with *Dichognathus* material from the lower Viola of Oklahoma, upper Plattin near St. Louis, Missouri, and the Guttenberg of southwest Wisconsin.

Occurrence.—Galena forms were found only in the Prosser. They are most abundant near the base and become increasingly scarce higher in the section. In many samples from the shaly lower Prosser, *Dichognathus typica* comprises the majority of the conodonts recovered. This species was recovered from Localities 3, 4, 5, 12.

Repository.—Figured hypotype, S.U.I., 10017.

Genus DISTACODUS Hinde, 1879
Type species: *Machairodus incurvus* Pander, 1856.

These forms were originally assigned to *Machairodus* by Pander in 1856. Because that name was preoccupied, Hinde (1879) proposed the name *Distacodus* for the genus but retained Pander's generic description. The genus includes simple cones, generally keeled anteriorly and posteriorly, having a carina on each of the lateral faces. Lindström (1954) stated that forms having carinae adjacent to the posterior margin should be placed in *Acontiodus*. Laterally compressed forms of this type such as *A. arcuatus*, *A. reclinatus*, and *A. rectus* Lindström lack the flat or concave posterior face which Pander's generic description states to be diagnostic of *Acontiodus*. Such forms more

nearly conform to *Distacodus* although the two genera grade into each other.

This genus has been described from European and North American strata whose age ranges from Lower to Upper Ordovician.

DISTACODUS PROCERUS Ethington, n. sp.
Pl. 39, fig. 8

Simple conical recurved dental unit whose base is laterally compressed and elongated antero-posteriorly. Cone tapers rapidly from base to point of maximum curvature and is slender distally. The tooth is sharply recurved at mid-height with the distal portion making an angle of 15–30° with the basal margin. Anterior and posterior edges of tooth sharp becoming prominently keeled below mid-length. Base flared slightly enclosing sharp pointed deep subconical cavity whose apex extends to point of greatest curvature. Both lateral faces bear longitudinal posteriorly directed costae which are immediately posterior to the midline below the point of maximum curvature and asymptotic to the posterior edge of the distal portion of the tooth. Frequently the costae are not equally developed on both faces. On most specimens the costae begin somewhat above the base of the tooth; only rarely do they extend to the base.

Remarks.—This form seems very close to *Acodus similaris* Rhodes from the Keisley Limestone of Westmorland. Rhodes states that the latter species occasionally has a groove developed on both lateral faces with one being very faint. Pander's original definitions are explicit in stating that *Distacodus* is carinate on both lateral faces whereas *Acodus* has only a single carina.

Occurrence.—These forms are common throughout the Dubuque (Locs. 1, 2, 7, 10, 11) and rare in the uppermost beds of the Stewartville (Locs. 7, 10).

Repository.—Figured holotype, S.U.I., 10018.

DISTACODUS FALCATUS Stauffer
Pl. 39, fig. 9

Distacodus falcatus STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 142, pl. 12, fig. 16; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 89.

Remarks.—Representatives of this species from the Galena Formation are in close agreement with Stauffer's figures. The sharp curvature, varying from 45° to a right angle, of the unit generally occurs somewhat below mid-length. Cross section of the tooth is subcircular with low anterior and posterior keels extending orally from the base. Above the zone of curvature the unit is twisted and the keels are lateral in position. Rarely the basal portion of the cusp bears low parallel longitudinal costae which disappear in the zone of lateral twisting.

Occurrence.—These forms occur throughout the Galena but are rare at all localities. Prosser specimens were obtained from Localities 3, 4, 12. The species was found in the Stewartville at Localities 2 and 9. It occurs in the Dubque at Localities 1, 10, 11.

Repository.—Figured hypotype, S.U.I., 10019.

DISTACODUS INSCULPTUS (Branson & Mehl)
Pl. 39, fig. 10

Phragmodus insculptus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 124, pl. 10, figs. 32–34; GRAVES & ELLISON, 1941, Univ. Missouri School Mines & Metallurgy, Bull., Tech. ser., v. 14, p. 6, pl. 3, fig. 1; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 146; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 310, pl. 21, figs. 136,153,154.

Simple dental units with posteriorly extended base and sharp anterior and posterior keels. Anterior keel is widest at base, narrows to mid-height of the tooth, and is less prominent from this point to the tip of the tooth. Posterior keel is narrow along oral edge of the base. The tooth is continuously curved throughout its entire length with maximum curvature just above the base. Lateral faces bear prominent carinae which are parallel to the posterior edge of the denticle and become progressively narrow from base to tip. A wide shallow groove bordered by sharp shoulders extends along the crest of each carina throughout its length. Base is laterally compressed anteriorly and flared laterally from beneath the midpoint of the tooth to the posterior edge enclosing a broad shallow basal cavity. A low carina, subparallel to the anterior margin, on one side of the anterior keel extends from the base to one fourth the height of the unit.

Remarks.—Specimens identified by Branson & Mehl as *Phragmodus insculptus* are

fragmentary, much of the base as well as the tip of the unit having been lost. The material figured by Graves & Ellison and by Rhodes is similarly broken. Branson & Mehl suggested a similarity to *Scolopodus;* however, Pander defined that genus as having rounded anterior and posterior margins. The species is placed in *Distacodus* owing to the presence of lateral carinae and keeled edges.

Occurrence.—These forms were recovered from the lower beds of the Dubuque (Locs. 7, 10) and from the upper Stewartville (Locs. 2, 6, 7, 9). They are rare in both units.

Repository.—Figured hypotype, S.U.I., 10020.

Genus DREPANODUS Pander, 1856.
Type species: *D. arcuatus* Pander, 1856

Pander established this genus for simple forms having sharp anterior and posterior edges and convex lateral faces. This group was subdivided into species on the basis of degree of curvature. Lindström (1954) drew attention to the assignment of many forms which fit this description to *Oistodus* owing to the presence of an expanded base. He amended Pander's diagnosis of *Drepanodus* to include only those forms whose posterior margin follows an uninterrupted curve from base to tip. Forms referred to *Oistodus* have a sharp angle between the oral edge of the base and the posterior edge of the distal part of the tooth. The genus has been reported from Australia and Europe, as well as North America, and is among the most abundant and widespread of Ordovician genera.

DREPANODUS HOMOCURVATUS Lindström
Pl. 39, fig. 16

Drepanodus homocurvatus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, p. 563, pl. 3, figs. 23,24,39; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 725, pl. 87, figs. 1–6,8.

Remarks.—This species was proposed by Lindström for those forms formerly referred to *Oistodus curvatus,* but which, according to his redefinition, belong in the genus *Drepanodus.* Considerable variation occurs within material from the Galena assigned to this species. All appear to be within the scope of the definition of the species as originally proposed by Branson & Mehl and emended by Lindström.

Occurrence.—This form is abundant throughout the entire Galena Formation. It was recovered from all members at each sampling locality.

Repository.—Figured hypotype, S.U.I., 10021.

DREPANODUS SUBERECTUS (Branson & Mehl)
Pl. 39, fig. 17

Oistodus suberectus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 111, pl. 9, fig. 7; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 136; RHODES, 1953, Royal Soc. London, Philos, Trans., ser. B, no. 647, v. 237, p. 225, pl. 21, figs. 93,94, pl. 22, figs. 166,167; AMSDEN, 1957, Oklahoma Geol. Survey, Circ. 43, p. 27.

Drepanodus suberectus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, p. 568, pl. 2, figs. 21, 22.

Oistodus? suberectus GLENISTER, 1957, Jour. Paleontology, v. 31, p. 726, pl. 86, figs. 12,14.

The specimens referred to this species agree closely to the original definition of Branson & Mehl and to the Maquoketa material identified by Glenister as *Oistodus? suberectus.*

Occurrence.—This is a common form in all members of the Galena. Specimens were obtained from each locality sampled.

Repository.—Figured hypotype, S.U.I., 10022.

Genus EOLIGONODINA Branson,
Mehl & Branson, 1951.
Type species: *E. robusta* Branson,
Mehl & Branson, 1951.

The authors of this genus recognized its similarity to *Ligonodina* Ulrich & Bassler but considered *Eoligonodina* to be distinctive owing to development of a deep thin walled cavity beneath the cusp. Rhodes (1954) discussed the two genera and concluded that the presence of a deep basal cavity is insufficient to merit erection of a new genus for these forms. Ulrich & Bassler (1926) considered a distinct separation of the denticles of the posterior bar to be a diagnostic feature of *Ligonodina.* This character has been reflected in the species which have subsequently been described by other authors. Comparison of the Iowa specimens here referred to *Eoligonodina* with the illustration of the Richmond species and *Ligonodina elongata, L. extensa,* and *L. valma* described by Rhodes from Wales shows a tendency in these Ordovician forms toward basal crowding or fusion of the denticles on

the posterior bar. This feature coupled with the deep basal cavity supports the validity of *Eoligonodina* as a distinct genus.

EOLIGONODINA ELONGATA (Rhodes)
Pl. 40, fig. 5

Ligonodina elongata RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 305–306, pl. 21, figs. 130,131.

Specimens from the Dubuque agree with the descriptions and figures of *Ligonodina elongata* Rhodes. The posterior bar is broken in all of the forms recovered. The oral edge is set with slender basally crowded erect denticles in a hindeodellid arrangment, i.e., every fourth or fifth denticle is approximately twice as large as the intervening teeth. The anterior inferior process makes an angle of 45° with the posterior bar and bears sharp slender discrete denticles along its anterior interior edge. These denticles decrease in size away from the cusp, those following the first being difficult to see except at high magnification, and are directed anteriorly parallel to the edge of the process. Distally these denticles curve slightly inward and extend to the base of the next anterior denticle.

Occurrence.—This species is rare in the Dubuque but was recovered from all localities where that formation was sampled (Locs. 1, 2, 7, 8, 10, 11).

Repository.—Figured hypotype, S.U.I. 10023.

EOLIGONODINA MAGNA Ethington, n. sp.
Pl. 40, figs. 3,4

Complex dental unit consisting of a slender, erect, or proclined cusp whose base is extended posteriorly as a deep arched sinous denticulate bar and aborally as a denticulate anterior aboral process. Cusp is subcircular in cross section with blunt anterior and posterior keels extending from base to tip. A plane through the keels makes an angle of about 45° with the plane of the posterior bar. The oral edge of the posterior bar is set with slender basally crowded conical denticles. Arrangement of denticles is hindeodellid with a gradual increase in size to the crest of the arched bar. The denticle in this position is equal to or greater than the size of the cusp. Anterior edge of the anterior aboral process is curved inward and bears a series of discrete slender denticles whose direction of growth parallels the edge of the process. The anterior aboral process and the posterior bar are connected by a pair of lateral sheath lamellae enclosing a horizontally directed conical cavity whose sharp apex extends into the base of the cusp. A posterior extension of this cavity forms a shallow groove along the aboral surface of the posterior bar.

Remarks.—This species appears to be close to *Subcordylodus* n. sp. figured by Branson (1944, pl. 13, fig. 19) from the Kimmswick. Some specimens of *E. magna* bear very small obscure denticles along the anterior aboral process. Such forms may represent an intermediate stage between *Subcordylodus* and *Eoligonodina.*

Occurrence.—*Eoligonodina magna* is rare in the Prosser (Locs. 3, 4) and Dubuque (Locs. 8, 10). No specimens were recovered from the Stewartville.

Repository.—Figured holotype, S.U.I., 10024.

Genus FALODUS Lindström, 1954.
Type species: *Oistodus prodentatus* Graves & Ellison, 1941.

Lindström (1954) discussed the diagnosis of the genus *Oistodus.* He remarked that one of the principal characters of this group as defined by Pander is that they are simple teeth and therefore multidenticulate forms such as *O. prodentatus* should be excluded. *Falodus* was proposed for such forms and defined as follows:

> Compound conodonts with two basal processes, one anteriorly, with denticles, and one posteriorly, without. There are no other processes or definite costae.

In addition to the type species, only one other, *F. extensus* (Graves & Ellison) from the Marathon Formation of West Texas, has been described. The genus ranges in age from Lower to Upper Ordovician and has been reported from southern Scotland, southern Sweden, New Jersey, and West Texas.

FALODUS PRODENTATUS (Graves & Ellison)
Pl. 39, fig. 18

Oistodus prodentatus GRAVES & ELLISON, 1941, Univ. Missouri School Mines & Metallurgy, Bull., Tech. ser., v. 14, p. 13,14, pl. 2, figs. 6, 22,23,28; FAY, 1952, Univ. Kansas Paleont., Contr., Vertebrata, art. 3, p. 136.

Falodus prodentatus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, p. 569, pl. 5, figs. 21, 22,30; LINDSTRÖM, 1957, Geol. Fören. Förhandl., Bd. 79, p. 164.

Falodus sp. LINDSTRÖM, 1957, ibid., Bd. 79, p. 173, pl. 1, figs. 25,26; LAMONT & LINDSTRÖM, 1957, Edinburgh Geol. Soc., Trans., v. 17, p. 63,64,65.

The material from the Galena Formation referred to this species is in complete agreement with the Texas forms described by Graves & Ellison. The British specimens illustrated by Lindström were found in slaty shale and chert and are poorly preserved. Nevertheless, they appear to be identical to the Iowa forms.

Occurrence.—This form is common in the uppermost beds of the Stewartville (Locs. 6, 7, 9) and the basal beds of the Dubuque (Locs. 7, 10, 11) but was not recovered from the upper beds of the latter. It is also found in the middle Prosser (Locs. 3, 4) but was not found in the lower shaly beds of that unit.

Repository.—Figured hypotype, S.U.I., 10025.

Genus GONIODONTUS Ethington, n. gen.
Type species: *G. superbus*

This genus includes complex dental units having a stout cusp, an anterior outer denticulate basal process, and posterior and anterior inner undenticulate processes. Basal outline of the cusp is triangular. Cusp has plane anterior face, convex posterior face, and sharp anterolateral edges resulting in a subtriangular cross section. Steeply inclined anterior process bears stout erect denticles alternating with one to two germ denticles. Inner anterior process is short. Posterior process has sharp oral edge which is continued as a sharp carina up the posterior face of the cusp and merges with the outer lateral edge at mid-height. A large hemipyramidal basal cavity beneath the cusp is extended as a wide shallow groove beneath each of the three processes.

Remarks.—Glenister figured a similar form from the phosphatic member of the Maquoketa Formation of Iowa and tentatively identified it as a species of *Ligonodina*. The latter genus is characterized by a denticulated anticusp and a posterior bar which bears widely spaced slender denticles. The denticulate process of the Dubuque and Maquoketa specimens is directed laterally as well as aborally and, therefore, is not an anticusp. *Ligonodina* does not have a basal process corresponding to the anterior inner basal process of *Goniodontus*.

GONIODONTUS SUPERBUS Ethington, n. sp.
Pl. 40, figs. 1,2

Complex dental units consisting of a stout erect cusp whose base gives off two unequal anterior lateral processes and a posterior process. Anterior face of the cusp is planar, whereas the posterior face is sharply convex giving the tooth a subtriangular cross section. A basal cavity extends well up into the cusp and is continued as wide shallow grooves beneath the three basal processes. The anterior outer lateral process, longest of the three, is inclined steeply away from the base of the cusp and is triangular in cross section. The oral edge bears at least two stout discrete denticles with convex anterior and posterior faces and sharp lateral edges. Direction of growth is at a low angle to the axis of the process. Spaces between the major denticles are occupied by one or two crowded germ denticles. The basal groove deepens beneath each of the major denticles and beneath the group of germ denticles. The anterior inner lateral process is short, stout, and nondenticulate. The posterior process is inclined slightly downward away from the posterior edge of the base of the cusp. The sharp oral edge of the posterior process continues as a prominent carina on the posterior face of the cusp, merging with the outer lateral edge at about mid-height.

Occurrence.—This form is rare in the Dubuque. It was obtained only from the exposure in northwestern Clayton County, from the roadcut east of Kendallville (Loc. 9) and from Locality 11 on the county line.

Repository.—Figured holotype, S.U.I., 10026.

Genus GYROGNATHUS Stauffer, 1935.
Type species: *G. primus* Stauffer, 1935.

Stauffer's definition of this genus based on material from the Glenwood of Minnesota included denticulate highly arched bars whose limbs are slightly twisted in opposite directions. The aboral surface of the bar is excavated by a groove which is deepest be-

neath the cusp. Ellison (1946) considered *Gyroganthus* to be a junior synonym of *Oulodus* Branson & Mehl. Rhodes (1953) regarded *Gyrognathus* as a valid genus containing forms resembling *Oulodus* but having a relatively thin blade-like aboral surface. The aboral surface of *Oulodus* (Branson & Mehl, 1944) is laterally expanded.

The genus has been recorded from rocks whose age ranges for Middle Ordovician to Upper Devonian. Ordovician forms are known from the Glenwood and Decorah of the Upper Mississippi Valley and from the Llandeilo and Gelli-grin Limestones of Wales.

GYROGNATHUS ELONGATA Rhodes
Pl. 40, fig. 13.

Gyrognathus elongatus RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 318–319, pl. 22, figs. 201,202,205,206.

Remarks.—The Iowa representatives of this form conform to Rhodes definition of the species. The twisted bars are fragile, tending to break transversely between the denticles, and no complete specimens were recovered.

Occurrence.—These forms are abundant in the Dubuque; and specimens were found in almost every sample taken from that unit. They are common in the upper beds of the Stewartville (Locs. 7, 9, 10). A few specimens were recovered from middle Prosser (Locs. 3, 4) but the genus does not occur in the lower, shaly portion of that unit.

Repository.—Figured hypotype, S.U.I., 10027.

Genus ICRIODELLA Rhodes, 1953.
Type species: *I. superba* Rhodes, 1953.

Rhodes' generic description (1953) is as follows:

> Narrow, elongated, platform-like dental units, with markedly irregular denticulation. Cusp stout, frequently developed at approximately mid-point of unit. Denticles anterior to cusp developed as low, conical projections along elevated oral ridge. Denticles posterior to cusp short, node-like, irregular, but generally decreasing in size posteriorly and having marked lateral elongation, so that, when viewed orally, they appear as a series of transverse bars.
>
> Sides deep and flaring at base, especially at base of cusp, where there is a deep anterior indentation on the outer aboral margin and a deep posterior indentation on the inner aboral margin giving prominent, opposed lateral flanges. Deep aboral excavation extending along entire length of unit.

This genus is very close to *Aphelognathus* Branson, Mehl & Branson, particularly in basal outline and nature of the basal cavity. The most distinctive character of *Icriodella* is the transverse bar-like development of the denticulation posterior to the apical denticle and the poorly developed character of the denticles on the anterior half of the unit. *Icriodella* has been previously reported only from the Upper Ordovician Gelli-grin and Pen-y-garnedd Limestones of Wales.

ICRIODELLA ACUTA Rhodes
Pl. 41, fig. 5

Icriodella superba var. *acuta* RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 288, pl. 20, figs. 59,60,64,66,71–73,77.

This species includes elongated dental units having the characteristic denticulation and sinuous basal outline of the genus. Cross section of the unit is acutely triangular with the base deeply excavated by a wide groove extending along the entire length, deepest beneath the apical denticle and becoming progressively shallow toward either end. In lateral view the base of the unit is slightly arched, and the oral surface slopes anteriorly and posteriorly away from the base of the cusp. The cusp is triangular in cross section, short, stout, and bears a prominent posterior lateral ridge which continues to the base of the unit forming a small outer lateral flange. A narrow anterior inner lateral flange extends forward from beneath the cusp to the anterior end. Denticles anterior to the cusp are short and nodose, varying from 5–10 in number, with a tendency to increase in size away from the cusp. Five to seven denticles are arranged along a sharp oral ridge posterior to the cusp and expand orally to form transverse bars. The center of each bar is somewhat concave, a character which, in extreme cases, gives the appearance of paired denticles on opposite sides of the oral ridge. The posterior denticles are separated from the cusp by a non-denticulate space.

Remarks.—This species is close to the type of the genus. It differs chiefly in the central depressions on the oral edges of the posterior

denticles and the shape of the cusp. A nondenticulate zone is present posterior to the cusp but the oral edge is not depressed in this region as it is in *I. superba*.

Occurrence.—This species is found only in the upper part of the Dubuque Member. At Locality 1 in Clayton County, this form is present in the top bed of the Dubuque just beneath the phosphatic zone of the Maquoketa, but does not occur in the samples taken lower in the exposure. It is found in the upper eight feet of the Dubuque at localities 7, 8, 11. The species does not occur in the material taken from either the quarry south of Kendallville (Loc. 10) or the Nordness quarry (Loc. 2) where only the basal Dubuque beds are exposed.

Repository.—Figured hypotype, S.U.I., 10028.

Genus KEISLOGNATHUS Rhodes, 1955.
Type species: *K. gracilis* Rhodes, 1955.

The generic definition as given by Rhodes (1955) is as follows:

> Complex dental units consisting of a stout fang and a denticulated posterior bar. On the anterior inner face of the fang a conspicuous pointed denticle is developed, which is extended downwards into a long, straight, slender, undenticulated aboral process. On the outer face of the fang an elongated, straight, denticulated outer lateral bar is developed. The aboral surfaces of the posterior and outer lateral bars and the anterior aboral processes are all deeply excavated.

Rhodes did not include hindeodellid denticulation in the generic definition but stated that this may prove to be an essential character when more specimens have been studied. Such denticulation occurs on all of the Iowa specimens and is probably characteristic of the genus. The genus has been described only from the Keisley Limestone of Westmorland in northern England.

KEISLOGNATHUS SIMPLEX Ethington, n. sp.
Pl. 40, figs. 9,10

The forms placed in this species are complex asymmetrical dental units having a stout, erect, or slightly proclined cusp which is broadly curved toward its base. A deep, laterally compressed denticulate bar extends posteriorly from the base of the cusp in a plane which is inclined inward in contrast to the vertical plane of the cusp. The oral surface of the posterior bar bears slender basally crowded sharp edged denticles in a hindeodellid arrangment. A stout circular denticle rises near the base of the inner lateral face of the cusp, curves orally parallel to the anterior margin of the unit, and is continued posteriorly as a laterally twisted anterior aboral process, proximally following the curvature of the cusp and distally straight. In larger specimens, the edge of this process is blunt or developed as a narrow face. The process is nondenticulate on most specimens but, rarely, small germ denticles may occur along its edge. A stout denticle is developed on the outer face of the cusp. Base of this outer lateral denticle extends downward posteriorly and laterally as an outer lateral bar which is more sharply curved in its proximal portion and therefore, in lateral view, makes a smaller angle with the posterior bar than the anterior aboral process. Cross section of the outer lateral bar is acutely triangular and its edge is set with a series of discrete conical denticles which grow forward parallel to the margin of the bar. The outer lateral bar, posterior bar, and anterior aboral process are mutually connected proximal to their junction with the cusp by lamellae enclosing a narrow cavity which extends anteriorly to a sharp point in the base of the cusp and is continued posteriorly as a groove beneath each of the three processes.

Remarks.—These forms appear to be close to *Roundya* but lack the characteristic bilateral symmetry. Occurrence of rare germ denticles on the anterior aboral process of some specimens may indicate a relationship to that genus. The Iowa forms do not differ greatly from *Keislognathus gracilis* Rhodes. Presence of a prominent denticle on both sides of the cusp is considered to be a specific difference although Rhodes indicates that in some of his specimens the most anterior denticle of the outer lateral bar was larger than those following. The anterior aboral process of *Keislognathus simplex* is twisted so that its edges are directed laterally; therefore, it could be considered as a second lateral process. In the author's opinion however, absence of denticulation is more significant than orientation in interpreting this process.

Occurrence.—These forms were recovered

from the Dubuque (Loc. 10, 11) and upper Stewartville (Loc. 9) but occur only rarely in either unit.

Repository.—Figured holotype, S.U.I., 10029.

Genus LOXOGNATHUS Graves & Ellison, 1941
Type species: *L. flabellata* Graves & Ellison, 1941.

To this genus belong complex dental units having a stout cusp and denticulate posterior bar. The base of the cusp projects downward as an anticusp and laterally as a denticulate outer lateral bar. The material from the Fort Peña Formation of West Texas on which this genus is based is not well preserved, particularly in the region of the anticusp. No denticles on the anticusp were noted for the Texas specimens whereas they are well developed on those from Iowa. Discovery of additional material from other regions may reveal this feature to be characteristic of the genus.

Ellison (1946) considered *Loxognathus* to be a synonym of *Dichognathus* which Branson & Mehl define as an antero-posteriorly elongate blade type of conodont with an apical denticle near the middle of the blade. The forms considered here do not fall within the scope of this definition and *Loxognathus* should be retained as a valid genus. It may stand close to *Periodon* Hadding described from beds in southern Sweden which Lindström (1955) considered to be approximately equivalent to the Chazyan of North America. *Periodon* is based on a figure published by Hadding in 1913 and has been described by Lindström (1955, p. 109,110, pl. 22, figs. 10, 11,14–16,35). Principal difference from *Loxognathus* is the lack of denticulation of the outer lateral bar.

LOXOGNATHUS GRANDIS Ethington, n. sp.
Pl. 40, fig. 6

In this species are included complex dental units having a slender cusp which is erect distally and curves posteriorly toward the base. The base of the cusp continues posteriorly as a highly arched laterally compressed denticulate posterior bar and aborally as a broad anticusp. Cross section of cusp is subcircular with low keels representing extensions of the anticusp and outer lateral process on the face of the cusp. Four to five slender discrete denticles rise on the inner surface of the anticusp near the anterior edge. The oral surface of the posterior bar is set with slender basally crowded anteriorly inclined denticles which increase in size away from the cusp. The denticle at the crest of the arch of the posterior bar equals or exceeds the cusp in size. All of the specimens recovered were broken at approximately this position, but a decrease in size of denticles posterior to the crest of the arch is suggested. An outer lateral process extends posteriorly, downward, and outward from the base of the cusp making an angle of about 30° with the posterior bar. The oral surface bears four to five discrete laterally compressed denticles with sharp anterior and posterior edges. Posterior bar, anticusp, and outer lateral process are mutually connected by thin lamellae enclosing a conical cavity which is extended anteriorly to a sharp point in the base of the cusp and continues posteriorly along each of the three processes as a narrow basal groove.

Occurrence.—This form is rare in the Dubuque (Loc. 10). Prosser specimens were recovered from the south Decorah roadcut (Loc. 3).

Repository.—Figured holotype, S.U.I., 10030.

Genus OISTODUS Pander, 1856.
Type species: *O. lanceolatus* Pander, 1856.

Pander's original description of this genus is not explicit in outlining generic characters. Simple forms having long wide excavated bases are specified. As emphasized by Lindström (1954), these are subjective characters and, as a result, a variety of forms have been placed in this genus, some of which can better be considered under *Drepanodus*. He redefined *Oistodus* to include simple forms with a pronounced basal cavity and generally having carinae on one or both lateral faces. The genus is distinguished from *Drepanodus* by the sharp angle in the posterior margin between the oral edge of the base and the posterior edge of the distal portion of the tooth.

The genus is restricted to rocks of Ordovician age and has been recorded from many localities in Europe and North America. *Oistodus larapintinensis* Crespin from

the Ordovician of central Australia is probably a *Drepanodus* close to *D. homocurvatus*.

Oistodus Abundans Branson & Mehl
Pl. 39, fig. 21

Oistodus abundans Branson & Mehl, 1933, Univ. Missouri Studies, v. 8, p. 109, pl. 9, figs. 11,17; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 134; Lindström, 1954, Geol. Fören. Förhandl., Bd. 76, p. 572; Amsden, 1957, Oklahoma Geol. Survey, Circ. 43, p. 35.

Remarks.—Representatives of this species from northeastern Iowa are in close agreement with the forms figured and described by Branson & Mehl. Most of the specimens have the posterior portion of the expanded base and the distal half of the tooth broken off. *Oistodus selene* Lindström from the Swedish Lower Ordovician is very similar to this species.

Occurrence.—This species occurs throughout the Prosser (Locs. 3, 4, 5, 12) and is abundant in some horizons particularly near the base of the unit.

Repository.—Figured hypotype, S.U.I., 10031.

Oistodus excelsus Stauffer
Pl. 39, fig. 20

Oistodus excelsus Stauffer, 1935b, Jour. Paleontology, v. 9, p. 610, pl. 74, fig. 43; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 135; Lindström, 1954, Geol. Fören. Förhandl., Bd. 76, p. 573; Glenister, 1957, Jour. Paleontology, v. 31, p. 725–726, pl. 86, figs. 4,7.

Remarks.—The material from the Galena Formation which is referred to this species exhibits all of the characters described and illustrated by Stauffer. Anterior and posterior keels are strongly developed on all specimens.

Occurrence.—The species is common throughout the Dubuque (Locs. 1, 2, 7, 8, 10, 11). It is also present but less abundant in the Prosser (Locs. 3, 4, 11) and Stewartville (Locs. 2, 6, 7, 10).

Repository.—Figured hypotype, S.U.I., 10032.

Oistodus fornicalus Stauffer
Pl. 39, fig. 19

Oistodus fornicalus Stauffer, 1935b, Jour. Paleontology, v. 9, p. 610, pl. 75, figs. 3–6; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 135; Lindström, 1954, Geol. Fören. Förhandl., Bd. 76, p. 573.

In this species are placed simple dental units consisting of a lanceolate sharply recurved denticle whose base is expanded posteriorly. Midline of distal portion of the unit is nearly horizontal in lateral view. The tooth is slightly twisted laterally above the base. Anterior and posterior edges of the blade are sharp; lateral surfaces are convex. Convexity of outer face is broken by a prominent shoulder, posterior to the midline of the tooth, extending from base to tip of the unit. Base is laterally compressed with a curved posterior oral edge which results in a semicircular outline when viewed from the side. A deep, narrow basal cavity projects to a sharp point near the point of maximum curvature of the tooth. The basal cavity and outer wall of the tooth are flared outward anterior to the outer lateral shoulder.

Remarks.—*Belodus?* sp. illustrated by Branson (1944, pl. 12, fig. 13) from the Kimmswick of Missouri has no denticles on the oral surface of the cusp and closely resembles *O. fornicalus* in general outline.

Occurrence.—This form occurs throughout the Galena but is rare in all of the samples from which it was recovered. It is present in the Prosser in Localities 3 and 4. Stewartville specimens occur in Localities 7 and 10, and it was recovered from the Dubuque in Localities 1, 8, 10, 11.

Repository.—Figured hypotype, S.U.I., 10033.

Oistodus venustus Stauffer
Pl. 39, fig. 22

Oistodus venustus Stauffer, 1935a, Geol. Soc. America, Bull., v. 46, p. 147, pl. 12, fig. 12; Fay, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 136; Lindström, 1954, Geol. Fören. Förhandl., Bd. 76, p. 573; Rhodes, 1954, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 295–296, pl. 22, figs. 168–170.

Remarks.—Rhodes (1954, p. 295–296) expressed the opinion that Stauffer's original description of the species based on material from the Glenwood of Minnesota is inadequate to distinguish it from such congeneric forms as *Oistodus abundans* Branson & Mehl.

He restricted *O. venustus* to those forms fitting the description in which the length of the base is approximately equal to that of the cusp. Dubuque and Stewartville specimens correspond closely to the emended specific description of Rhodes and to his illustrations of Middle Ordovician forms from Wales. The Maquoketa specimen referred to this species by Glenister has a much shorter base and probably belongs in *Oistodus excelsus*.

Occurrence.—These forms are common throughout the Dubuque (Locs. 1, 2, 7, 8, 10, 11) and in the upper beds of the Stewartville at Localities 7 and 10.

Repository.—Figured hypotype, S.U.I., 10034.

Genus OZARKODINA Branson & Mehl, 1933.
Type species: *O. typica* Branson & Mehl, 1933.

This genus was first described by Branson & Mehl on the basis of material from the Silurian Bainbridge Formation of Missouri. It includes arched denticulate blades bearing an apical denticle near the center of the oral edge. A prominent subapical navel extends to both ends of the unit as an aboral groove. The genus has been reported from North American and European strata whose age ranges from Middle Ordovician to Lower Permian.

OZARKODINA CONCINNA Stauffer
Pl. 41, figs. 15,16

Ozarkodina concinna STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 148, pl. 10, figs. 41,45, 46; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 137; SWEET, 1955, Jour. Paleontology, v. 29, p. 260, pl. 29, fig. 18.
Ozarkodina inclinata GLENISTER, 1957, Jour. Paleontology, v. 31, p. 735, pl. 88, figs. 3,7.

Remarks.—This species has been reported from numerous Ordovician localities by various authors. Stauffer found it in the Glenwood and Decorah faunas, Sweet illustrated it from the Harding of Colorado, Branson from the Kimmswick of Missouri; Furnish, *et al.* figured a Whitewood specimen from South Dakota. These authors have assigned forms showing wide variations to this species. Stauffer's original figures allow considerable variance; his later illustrations of specimens from the Decorah Formation and from a clay in the vicinity of Austin, Minnesota most nearly resemble Plate 10, figure 41 of the earlier Glenwood report. The form from the Dutchtown of Missouri assigned to this species by Branson (1944) may not be an *Ozarkodina*. The Maquoketa material which Glenister described as *O. inclinata* falls within the limits of variation of *O. concinna* and is probably conspecific.

The greatest variation in this species is in the number of denticles and in the width of the aboral surface. Stauffer's definition describes six or seven denticles anterior to the apical denticle. Other authors have included forms having a similar configuration but as many as 12 anterior denticles. The majority of the specimens examined in this study have six or seven anterior denticles although larger forms have eight or ten. Differences in number of denticles may be the result of differences in stage of growth. At the anterior end, most complete specimens have a low knob which may represent a germ denticle, thus indicating that new denticles are added anteriorly.

Occurrence.—This is one of the most common forms in the Dubuque and upper Stewartville beds and was recovered from these members at all localities where they were collected. The species is present in lower Prosser (Locs. 3, 4, 12) but relatively rare.

Respository.—Figured hypotypes, S.U.I., 10035, 10036.

OZARKODINA DELECTA Stauffer
Pl. 41, fig. 17

Ozarkodina delecta STAUFFER, 1935a, Geol. Soc. America, Bull., v. 46, p. 148,159, pl. 10, fig. 40; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 137; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 735, pl. 88, figs. 8,9.

Remarks.—Specimens of this species from the Galena agree closely with the forms figured by Glenister from the basal phosphatic member of the Maquoketa. Commonly the tip of the apical denticle or half of the blade has been lost. The Kimmswick forms illustrated by Branson (1944, pl. 12, figs. 14–17) as *Ozarkodina* n. sp. may belong in this species.

Occurrence.—These are common forms in the Dubuque (Locs. 1, 2, 7, 8, 10, 11) and

upper Stewartville (Locs. 2, 6, 7, 9, 10). They are rare in the Prosser (Locs. 3, 4).

Repository.—Figured hypotype, S.U.I., 10037.

OZARKODINA MACRODENTATA Graves & Ellison
Pl. 41, fig. 14

Ozarkodina macrodentata GRAVES & ELLISON, 1941, Univ. Missouri School Mines & Metallurgy, Bull., Tech. ser., v. 14, p. 14, pl. 2, figs. 33,35,36; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 138.

Remarks.—This species is close to *Ozarkodina delecta.* It differs chiefly in greater inclination of the apical denticle on which prominent anterior and posterior keels are developed. Denticles of *O. macrodentata* are more closely crowded basally. The blade is deeper than that of *O. delecta,* and the flaring basal cavity occupies more than half of the aboral surface.

Occurrence.—This form is rare in lowermost Dubuque (Loc. 10), upper Stewartville, (Locs. 7, 9) and in the Prosser (Locs. 3, 4, 12).

Respository.—Figured hypotype, S.U.I., 10038.

Genus PANDERODUS Ethington, n. gen.
Type species: *Paltodus unicostatus* Branson & Mehl, 1933.

In this genus are placed simple asymmetrical curved cones which have a deep, tapered, basal cavity generally extending at least to mid-height. Lateral faces are ornamented by costae or grooves; cross section of the tooth may be used for specific identification. Basal outline tends to be broadly rounded anteriorly and narrow posteriorly.

Remarks.—Pander defined the genus *Paltodus* for asymmetrical curved conodonts. His generic description does not specify the shape of the basal cavity in this genus but his figures indicate that it is shallow. A variety of North American and European forms with deeply excavated bases have been assigned to this genus by many authors on the basis of asymmetrical cross sections. Furnish (1938) concluded that the cross sections of simple conodonts show such gradational variations as to be unsatisfactory for generic differentiation. Presence of a deep basal cavity is a common character of all species from strata younger than Lower Ordovician which have been placed in the genus *Paltodus.* The genus *Panderodus* is proposed to include all forms of this type. In addition to the six species described by Pander from the Baltic region, *P. inconstans* Lindström is retained in *Paltodus.* Thus defined, *Paltodus* is known only from northern European strata of Lower Ordovician age. *Panderodus* ranges from Lower Ordovician to Middle Silurian and has been reported from many localities in Great Britain and North America. Forms from the Waterhouse Range of Central Australia which Crespin (1943) placed in *Paltodus* probably belong here also.

Specific subdivision of *Panderodus* is based on the curvature and cross section of the tooth. Material from northeastern Iowa studied during the present investigation represents a gradational series of variations. These forms have been assigned to five species which are considered to represent definite trends in the series.

PANDERODUS COMPRESSUS (Branson & Mehl)
Pl. 39, fig. 4

Paltodus compressus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 109, pl. 8, fig. 19; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 143; AMSDEN, 1957, Oklahoma Geol. Survey, Circ. 43, p. 35.

Remarks.—Laterally compressed regularly curved forms bearing a groove parallel to the posterior margin on one lateral face are placed in this species. Prosser forms tend to be larger than those from the Dubuque and Stewartville.

Occurrence.—This species is common in the Prosser (Locs. 3, 4, 5, 12), and rare in the Stewartville and Dubuque (Locs. 7, 10).

Repository.—Figured hypotype, S.U.I., 10039.

PANDERODUS FEULNERI (Glenister)
Pl. 39, fig. 2

Paltodus feulneri GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, fig. 11.

Remarks.—Representatives of this species from the Galena are identical to Glenister's type specimens from the Maquoketa. Varia-

tions in size are probably caused by different stages of growth.

Occurrence.—Although not abundant at any horizon, this form occurs throughout the Dubuque at all localities and was recovered from almost all samples taken. It also occurs rarely in the upper Stewartville (Locs. 2, 7, 9, 10) and Prosser (Locs. 3, 4).

Repository.—Figured hypotype, S.U.I., 10040.

PANDERODUS GRACILIS (Branson & Mehl)
Pl. 39, fig. 1

Paltodus gracilis BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 108, pl. 8, figs. 20,21; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 144; AMSDEN, 1957, Oklahoma Geol. Survey, Cir. 43, p. 35; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, figs. 2–5.

Remarks.—A variety of forms having broadly rounded anterior edges and blunt to relatively sharp posterior edges is included here. The range of variations shown by Glenister in Maquoketa material also occurs in the Galena specimens.

Occurrence.—*Panderodus gracilis* is abundant throughout the Prosser, Stewartville and Dubuque. It was found in all samples collected.

Repository.—Figured hypotype, S.U.I., 10041.

PANDERODUS INTERMEDIUS (Branson, Mehl, & Branson)
Pl. 39, fig. 3

Paltodus intermedius BRANSON, MEHL & BRANSON, 1951, Jour. Paleontology, v. 25, p. 7, pl. 1, figs. 9–15; GLENISTER, 1957, ibid., v. 31, p. 728, pl. 85, fig. 10.

Remarks.—Representatives of this species considered in the present study agree in all respects with those figured by Glenister from the Maquoketa of Iowa and by Branson, *et al.* from the Upper Richmond formations of Kentucky.

Occurrence.—This form is common throughout the Galena Formation. It was present in all samples collected.

Repository.—Figured hypotype, S.U.I., 10042.

PANDERODUS PANDERI (Stauffer)
Pl. 39, fig. 5

Paltodus panderi STAUFFER, 1940, Jour. Paleontology, v. 14, p. 427, pl. 60, figs. 8,9; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art 3, p. 144; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728,729, pl. 85, figs. 8,9.

Remarks.—The Galena forms placed in this species conform to the extended description given by Glenister for Maquoketa material.

Occurrence.—This species is rare in the Dubuque. A few specimens were recovered from each of Localities 1, 2, 7, 8, 10, 11.

Repository.—Figured hypotype, S.U.I., 10043.

Genus PHRAGMODUS Branson & Mehl, 1933.
Type species: *P. primus* Branson & Mehl, 1933.

Branson & Mehl erected this genus to include complex dental units having a denticulate posterior bar with a stout, proclined, or erect cusp. The cusp is separated from a large superior denticle of comparable size on the oral edge of the posterior bar by a number of smaller denticles and is continued downward and backward as an anticusp. A deep thin walled basal cavity extends into the base of the cusp.

In some Middle Ordovician forms the posterior bar behind the superior denticle is sinuous in outline and generally has been broken from the rest of the specimen. The genus *Pravognathus*, replacing *Heterognathus* which is preoccupied, was established by Stauffer for such fragments.

Phragmodus has been described from Middle and Upper Ordovician strata of North America. It is probably close to *Periodon* which Lindström and Hadding have illustrated from the Lower Ordovician of Sweden. The specimens from Wales and North America which have been identified as *Phragmodus insculptus* are here considered to belong in *Distacodus*.

PHRAGMODUS UNDATUS Branson & Mehl
Pl. 41, fig. 12

Phragmodus undatus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 115–116, pl. 8, figs. 22–26; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 146; AMSDEN, 1957, Oklahoma Geol. Survey, Circ. 43, p. 35; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 733, pl. 88, figs. 1,2.

Remarks.—Well preserved specimens of

this species are locally abundant in the Galena. Forms comparable to the complete range of variations cited by Glenister from Maquoketa material are found. Prosser specimens tend to be more robust than those from either the Dubuque or Stewartville. The Galena forms agree closely with comparative material from the lower part of the Viola of Oklahoma, the upper Plattin near St. Louis, and the Guttenberg of Wisconsin.

Occurrence.—*Phragmodus undatus* is rare in the Stewartville (Loc. 7) and Dubuque (Loc. 11). The species is abundant in the shaly lower part of the Prosser but less common in the upper half of the unit. Together with *Panderodus* spp. and *Dichognathus typica*, this species makes up the greater part of the conodont fauna of the basal Prosser.

Repository.—Figured hypotype, S.U.I., 10044.

Genus RHYNCHOGNATHUS Ethington, n. gen.
Type species: *R. typica* Ethington

The genus *Rhynchognathus* is erected to include asymmetrical dental units having a stout proclined curved cusp whose base is produced posteriorly as a shallow denticulate bar. The anterior margin of the cusp is continued posteriorly as a slender aboral process, which may be denticulate in the plane of the posterior bar. A lateral denticulate bar extends posteriorly, aborally, and laterally from the base of the cusp. The conical, peg-like denticles of the posterior bar alternate in size and, in some specimens, a rudimentary hindeodellid arrangement may be developed. The three processes are mutually connected by sheath lamellae which enclose a hemipyramidal basal cavity extending anteriorly to a sharp point in the base of the cusp.

Remarks.—The general hemipyramidal shape of these units and the large cavity are similar to *Sagittodontus*. The latter genus differs in being almost completely lacking in denticulation. Alternation in size of the denticles of the oral edge may indicate a similarity to *Tetraprioniodus parvus* and *Keislognathus simplex* which have hindeodellid posterior bars. Forms having denticles rising along all three processes bear a superficial resemblance to *Trichonodella* but lack the symmetry of that genus.

RHYNCHOGNATHUS TYPICA
Ethington, n. sp.
Pl. 41, figs. 3,4

Complex dental units having a short stout proclined cusp which curves slightly inward. The base of the cusp is continued posteriorly as an oral denticulated bar, an outer lateral denticulated bar, and an aboral undenticulated process, all of equal length. Thin laminae connect the aboral edges of the proccesses to sheath a hemipyramidal cavity whose apex penetrates into the base of the cusp. The lamina joining the posterior bar and aboral process is convex whereas the laminae connecting the lateral bar to the posterior bar and aboral process are slightly concave. Oral edge of the posterior bar is set with peg-like, basally crowded, erect denticles which alternate in size. The oral surface of the outer lateral bar faces laterally and bears short discrete conical denticles which are inclined posteriorly and whose direction of growth curves orally. In lateral view, the lateral bar makes an angle of 20°–30° with the posterior bar. The aboral process continues the curvature of the anterior margin of the cusp and becomes straight distally. Anteriorly all three processes are continued orally as carinae which extend to mid-height of the cusp.

Occurrence.—This species was recovered only from the upper 10 feet of the Dubuque (Locs. 1, 7, 8) where it occurs with *Sagittodontus* and *Icriodella*.

Repository.—Figured holotype, S.U.I., 10045.

RHYNCHOGNATHUS ABORODENTATA
Ethington, n. sp.
Pl. 41, figs. 1,2

Complex asymmetrical dental units having a stout proclined cusp, gently curved throughout its entire length. Base of cusp is produced posteriorly as three denticulate processes of equal length which are directed posteriorly, aborally, and laterally respectively. The posterior bar is stout and deep bearing along its oral edge a series of short peg-like conical denticles which alternate in size. Rarely pairs of small denticles alternate

with single large denticles in a sub-hindeodellid manner. Viewed vertically, the posterior bar is subtriangular in cross section with the sharp oral edge oriented outward. Short conical discrete denticles grow forward at an angle of approximately 45° to the edge of the bar and curve upward. Denticles of the lateral bar alternate in size. The denticles of the anterior aboral process rise along the inner edge and grow forward at a low angle to the margin of the process; the tip of each denticle is adjacent to the base of the next anterior denticle. Concave sheath lamellae connect all three processes to enclose a hemipyramidal basal cavity which extends anteriorly into the base of the cusp.

Occurrence.—Like *Rhynchognathus typica*, this species was recovered only from the upper beds of the Dubuque (Locs. 1, 7, 8). No specimens were obtained from the lower 15 feet of that member.

Repository.—Figured holotype, S.U.I., 10046.

Genus SAGITTODONTUS Rhodes, 1953
Type species: *S. robustus* Rhodes, 1953

Rhodes definition of this genus (1953) is as follows:

> General appearance barb-like; single, large stout denticle, triangular in cross-section with three more or less flattened faces and sharp dividing edges, the lower part of each face usually having a wide, shallow depression. Unit expanded at base into hemipyramidal form. Edges gently curved. Irregular aboral margin; aboral surface deeply excavated so that whole unit is hollow.

Irregular indentations of one of the edges are noted but not interpreted as denticles. Rhodes concluded that the genus lacks secondary denticulation. Similar indentations occur along the edges of the larger Iowa forms and in the smaller forms low, node-like denticles are found in this position. Faint secondary denticulation may characterize the genus, particularly in early growth stages.

Lindström (1954) suggested that *Sagittodontus* should be regarded as a junior synonym of *Acodus*. However the barb-like general appearance, presence of faint denticulation, the deeply excavated base, and the concavity of the faces of these teeth support the validity of *Sagittodontus*.

The genus has been reported from the Upper Orodovician Gelli-grin Limestone of Wales and from units in the Randschiefer Series of Bavaria which Sannemann (1955) concluded to be of Lower or Middle Ordovician age.

SAGITTODONTUS DENTATUS
Ethington, n. sp.
Pl. 39, fig. 13

This species is proposed for simple stout teeth, which curve posteriorly and inward toward the tip. Base of the unit flares laterally to form a broad hemipyramid with convex anterior edge and concave posterior and lateral edges. Anterior edge bears at least five short vertically directed denticles. Basal outline is approximately an equilateral right triangle. A deep basal cavity extends nearly to the tip of the unit. All faces of the tooth are concave.

Occurrence.—This species was recovered only from the upper beds of the Dubuque (Locs. 1, 7, 8).

Repository.—Figured holotype, S.U.I., 10047.

SAGITTODONTUS ROBUSTUS Rhodes
Pl. 39, fig. 12

Sagittodontus robustus RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 311, pl. 21, figs. 141,142.

This species includes stout simple teeth having a triangular cross section. Tip of tooth is erect or curved posteriorly and inward. Base is expanded to form a hemipyramid with anterior, posterior, and outer-lateral edges of equal length. Outer lateral faces are equal in width and less wide than the inner face. Each face of the unit becomes increasingly concave toward the base so that the inner surfaces almost touch in the center of the basal cavity. Anterior and posterior edges are sharply keeled; outer lateral edge may be smoothly rounded or keeled. Base is deeply excavated by a thick walled cavity which extends almost to the tip of the unit. Constrictions owing to the concavity of the faces of the unit divide the cavity into three narrow, mutually connected lobes. Triangular basal outline has angles of 45°, 45°, and 90°. Smaller specimens bear faint germ

denticles on the anterior and posterior edges. Larger specimens have serrate edges in this position, indicating former location of denticles.

Remarks.—Bavarian material on which *Sagittodontus gracilis* Sannemann is based is very close to *S. robustus.*

Occurrence.—The Iowa forms are restricted to the upper 10 feet of the Dubuque (Locs. 1, 7, 8). No specimens were recovered from those exposures where only the lower beds of the Dubuque are exposed.

Repository.—Figured hypotype, S.U.I., 10048.

Genus SUBCORDYLODUS Stauffer, 1935.
Type species: *S. elongatus* Stauffer, 1935

Remarks.—Ellison (1946) suggested that this genus is a synonym of *Cordylodus* Pander. Rhodes (1953) concurred and expressed the opinion that no significant difference exists between *Cordylodus* and *Subcordylodus.* Sweet (1955) recognized similarity of the two genera but considered them both to be valid. He placed those forms having a distinct denticulate aborally grooved posterior bar in *Subcordylodus,* whereas those having denticles arising from the oral surface of a sheathed basal cavity are considered under *Cordylodus.* The author agrees with the latter opinion.

SUBCORDYLODUS DELICATUS
(Branson & Mehl)
Pl. 41, fig. 13

Cordylodus? delicatus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, p. 129, pl. 10. figs. 14,15; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 82; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 731–732, pl. 88, fig. 5.

Subcordylodus delicatus BRANSON, 1944, Univ. Missouri Studies, v. 19, p. 89,90, pl. 13; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 194.

Cordylodus rectilineatus RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 300–301, pl. 22, figs. 172–175.

Remarks.—Material from the Galena Formation which is referred to this species agrees closely with Branson & Mehl's illustration of a specimen from the Maquoketa of Missouri. It is identical to the forms from the Maquoketa of Iowa described by Glenister and tentatively placed in *Cordylodus.*

In North America the species is known from the Kimmswick of Missouri and the Maravillas of West Texas. It has also been reported from the Llandeilo Limestone of Wales. Range is Middle to Upper Ordovician.

Occurrence.—This form is ubiquitous in the Dubuque. It is common in the Stewartville (Locs. 2, 6, 7, 9, 10, 11) and less common in the middle Prosser (Locs. 3, 4).

Repository.—Figured hypotype, S.U.I., 10049.

Genus TETRAPRIONIODUS Lindström, 1954
Type species: *T. robustus* Lindström, 1954.

This taxon was erected by Lindström to include compound conodonts having an anterior cusp, a posterior denticulate bar, two lateral denticulate bars, and an anterior aboral process which may bear denticles. *Rosagnathus* Rhodes, 1955, is a junior synonym of this genus. The genus has been described previously from the Lower Ordovician of Sweden where two species are known. Another species has been reported from the Upper Ordovician Keisley Limestone of Westmorland.

TETRAPRIONIODUS PARVUS
Ethington, n. sp.
Pl. 40, fig. 8

Complex dental units having a slender cusp which is erect throughout the greater part of its length and slightly curved posteriorly at its base. Each lateral face of the cusp is ornamented by a low longitudinal costa which becomes less prominent toward the tip. The posterior bar is deep, has an acutely triangular cross section, and is excavated aborally by a narrow groove. The oral surface bears a hindeodellid series of short laterally compressed sharp edged denticles. The lateral bars are inclined downward and posteriorly making an angle with the posterior bar of approximately 20° in lateral view. Cross sections of the lateral bars are acutely triangular with deep, narrow basal grooves. Widely separated denticles rise from the oral surface and are directed forward parallel to the edges of both bars. The outer lateral bar terminates an-

teriorly in a heavy denticle which curves orally and is parallel to the edge of the cusp. Both lateral bars are continued up the side of the cusp as low costae and twisted so that their excavated aboral surfaces are facing toward the center of the unit. An anterior aboral process rises on the inner side of the anterior margin of the cusp and curves aborally and posteriorly with the straight distal portion making an angle of 45° with the posterior bar when viewed laterally. The process is continued orally as a stout denticle which is generally recurved parallel to the margin of the cusp. Well preserved specimens show thin sheath lamellae mutually connecting the posterior and lateral bars and the anterior aboral process to enclose a small cavity which tapers to a sharp point in the base of the cusp.

Remarks.—These forms are similar to *Tetraprioniodus superbus* (Rhodes) but differ in the greater length of the anterior aboral process and the smaller number of denticles on the lateral bars.

Occurrence.—This form was recovered only from the Dubuque Formation (Locs. 7, 10, 11). It is rare with greatest concentration occurring in the basal beds.

Repository.—Figured holotype, S.U.I., 10050.

Genus TRICHONODELLA Branson & Mehl, 1948
[=TRICHOGNATHUS Branson & Mehl, 1933.]
Type species: *Trichognathus prima* Branson & Mehl, 1933.

Remarks.—Hass (1953) established the genus *Roundya* to include those forms formerly assigned to *Trichonodella* which bear a posterior denticulate bar. Sweet (1955) considered the Ordovician forms of this type to be more nearly related to *Trichonodella* than to *Roundya* and advocated their retention in the former genus. The author is in accord with this opinion. In all Ordovician trichonodellids possessing a posterior bar, this process is laterally compressed and deep with closely crowded or partially fused, sharp edged denticles. The type species of *Roundya* and post Ordovician forms included in that genus have stout posterior bars, generally wider than deep, bearing slender discrete denticles which tend to be widely separated along the bar. Such forms are closer to *Ellisonia* Müller and *Hibbardella* Ulrich & Bassler than to the Ordovician trichonodellids. *Trichonodella* ranges in age from Lower Ordovician to Lower Silurian. The younger forms which have been referred to this genus probably all belong in *Roundya*.

TRICHONODELLA INSOLITA
Ethington, n. sp.
Pl. 41, fig. 9

This species is established for complex dental units having a proclined basally curved cusp. A deep laterally compressed arched posterior bar joins the cusp at its base. The oral surface bears crowded laterally compressed denticles with sharp anterior and posterior edges. The first 4–6 denticles posterior to the cusp are erect and tend to increase slightly in size away from the cusp. These are succeeded by at least 3–4 much larger anteriorly inclined teeth which are equal to or greater in size than the cusp. The posterior bar is broken on all specimens recovered. Lateral bars are given off from the basal anterior margin of the cusp and continue its curvature posteriorly, becoming almost horizontal distally, and forming an angle of 30° with each other. Low discrete denticles are given off from the oral edges of the lateral bars and grow forward parallel to the bar. The lateral bars and posterior bar are mutually connected by thin lamellae enclosing a cavity which extends forward to a sharp point in the base of the cusp and is continued posteriorly as deep grooves along the aboral surfaces of the bars.

Remarks.—The nature of the denticulation of the posterior bar of this species suggests a relationship to *Loxognathus grandis*. It is very close to *Trichonodella flabellum* Lindström from the Lower Ordovician of Sweden, differing primarily in the angle between the lateral bars. The denticulation and lateral outline are similar to some of the specimens of *Periodon aculeatus* Hadding figured by Lindström (1955, pl. 22, figs. 10,11).

Occurrence.—This form is rare in the Dubuque (Loc. 10). A single specimen was

recovered from the upper beds of the Stewartville (Loc. 7).

Repository.—Figured holotype, S.U.I., 10051.

TRICHONODELLA EXACTA Ethington, n. sp.
Pl. 41, figs. 10,11

Complex dental units consisting of a slightly recurved cusp from whose base are produced a posterior and two denticulate lateral bars. In lateral view the latter make an angle of 75°–80° with the horizontal posterior bar and, viewed anteriorly, diverge at an angle of 45°–50°. Both lateral bars are slightly twisted so that their oral edges are oriented antero-laterally and bear 5–7 short wide laterally compressed denticles. The denticle adjacent to the cusp on both lateral bars is smaller than the others and may be fused with or crowded to the front of the base of the cusp. Anterior margin of the cusp is keeled, lateral faces are convex with a sharp posterior edge that merges with the oral edge of the posterior bar. The posterior bar is broken on all specimens recovered. It is deep, laterally compressed, and bears at least four low sharp edged denticles. Thin laminae join the three bars together to form a hemipyramidal basal cavity whose apex reaches up into the base of the cusp. The basal cavity is continued distally as wide grooves along the aboral surface of each of the bars.

Remarks.—This form is similar to *Trichonodella erecta* Branson & Mehl but differs in the angle between the lateral bars. The denticulation of the lateral bars is suggestive of *Trichonodella flexa* which lacks a posterior bar.

Occurrence.—Rare fragmentary forms close to *Trichonodella exacta* were recovered from the Prosser (Loc. 3) and Stewartville (Loc. 10). The species is common in the Dubuque (Locs. 1, 2, 7, 8, 10, 11).

Repository.—Figured holotype, S.U.I., 10052.

TRICHONODELLA FLEXA Rhodes, 1953.
Pl. 41, figs. 7,8

Trichonodella flexa RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 313–314, pl. 22, figs. 181–183,188,189,191, 192; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 734, pl. 88, fig. 13.

Remarks.—Well preserved material from the Dubuque conforms closely to Rhodes description of the species. The Iowa specimens tend to have six or seven denticles on each lateral bar rather than five as described by Rhodes.

Occurrence.—These forms are abundant in the Dubuque (Locs. 1, 2, 7, 8, 10, 11) but rare in the Prosser (Locs. 3, 4) and Stewartville (Locs. 2, 6, 7, 9, 10).

Repository.—Figured hypotype, S.U.I., 10053.

TRICHONODELLA INCLINATA Rhodes
Pl. 41, fig. 6

Trichonodella inclinata RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 315, pl. 22, figs. 176,177,186.

Roundya inclinata RHODES, 1955, Geol. Soc. London, Quart. Jour. v. 111, p. 137; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 733–734, pl. 88, fig. 19.

Remarks.—Like the Maquoketa forms figured by Glenister, Dubuque specimens referred to this species have vertical denticles on the posterior bar whereas Rhodes type specimens from Wales have slightly inclined denticulation. In this character the Iowa material is nearer to *Trichonodella diminuta* (Rhodes). The latter species has an erect cusp and lacks denticulation on the lateral bars. The species occurs in the same Dubuque strata as *Keislognathus simplex* and, because both have hindeodellid denticulation, the two forms are very similar in lateral view. They can be distinguished owing to the undenticulate process of *Keislognathus* and its lack of symmetry. Both these forms are close to *Tetraprioniodus parvus*, differing chiefly in the presence of an anterior aboral process in the latter species.

Occurrence.—This species occurs rarely in the Dubuque (Locs. 1, 2, 7, 10).

Repository.—Figured hypotype, S.U.I., 10054.

REFERENCES

AGNEW, A. F., 1955, Facies of Middle and Upper Ordovician rocks of Iowa: Am. Assoc. Petroleum Geologists, Bull., v. 39, p. 1702–1952.

AMSDEN, T. W., 1957, Catalog of Middle and Upper Ordovician fossils of Oklahoma: Oklahoma Geol. Survey, Circ. 43, 41 p.

—— & MILLER, A. K., 1942, Ordovician conodonts from the Bighorn mountains of Wyoming: Jour. Paleontology, v. 16, p. 301–306, pl. 41.

BRANSON, E. B., 1944, The geology of Missouri: Univ. Missouri Studies, v. 19, no. 3, 535 p., 49 pls.

—— & BRANSON, C. C., 1947, Lower Silurian conodonts from Kentucky: Jour. Paleontology, v. 21, p. 549–556, pls. 81,82.

—— & MEHL, M. G., 1933, Conodont studies: Univ. Missouri Studies, v. 8, 349 p., 28 pls.

—— & ——, 1944, Conodonts. *In* Index Fossils of North America: H. W. Shimer & R. R. Shrock, New York, p. 235–256, pls. 93,94.

——, ——, & BRANSON, C. C., 1951, Richmond conodonts of Kentucky and Indiana: Jour. Paleontology, v. 25, p. 1–17, pls. 1–4.

CALVIN, SAMUEL & BAIN, H. F., 1899, Geology of Dubuque County: Iowa Geol. Survey, Ann. Rept., v. 10, p. 379–622, pls. 4–11.

COOPER, G. A., 1956, Chazyan and related brachiopods: Smithsonian Misc. Coll., v. 127, 1245 p., 269 pls.

CRESPIN, IRENE, 1943, Conodonts from Waterhouse Range, Central Australia: Royal Soc. Australia, Trans., v. 67, p. 231–232, pl. 31.

DUNCAN, HELEN, 1956, Ordovician and Silurian coral faunas of western United States: U. S. Geol. Survey, Bull. 1021-F, p. 209–236, pls. 21–27.

ELLISON, S. J., JR., 1946, Conodonts as Paleozoic guide fossils: Am. Assoc. Petroleum Geologists, Bull., v. 30, p. 93–110.

FAY, R. O., 1952, Catalogue of conodonts: Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 1–206.

FLOWER, R. H., 1957a, The cephalopod order Discosorida: Univ. Kansas Paleont. Contr., Mollusca, art. 6, 144 p., 43 pls.

——, 1957b, Studies of the Actinoceratida: New Mexico Inst. Mines and Mineral Res., Mem. 2, 73 p., 13 pls.

——, 1958, Some Chazyan and Mohawkian Endoceratida: Jour. Paleontology, v. 32, p. 433–458, pls. 59–62.

FOERSTE, A. F., 1929a, The Ordovician and Silurian of American arctic and subarctic regions: Denison Univ. Bull., Jour. Sci. Labs., v. 26, p. 27–79, pls. 2,3.

——, 1929b, The cephalopods of the Red River Formation of southern Manitoba: Denison Univ. Bull., Jour. Sci. Labs., v. 24, p. 129–235, pls. 11–39.

——, 1935, Bighorn and related cephalopods: Denison Univ. Bull., Jour. Sci. Labs., v. 30, p. 1–96, pls. 1–22.

FURNISH, W. M., 1938, Conodonts from the Prairie du Chien beds of the Upper Mississippi Valley: Jour. Paleontology, v. 12, p. 318–340, pls. 40,41.

——, BARRAGY, E. J., & MILLER, A. K., 1936, Ordovician fossils from upper part of type section of Deadwood Formation, South Dakota: Am. Assoc. Petroleum Geologists, Bull., v. 20, p. 1329–1341, 2 pls.

GLENISTER, A. T., 1957, The conodonts of the Ordovician Maquoketa Formation in Iowa: Jour. Paleontology, v. 31, p. 715–736, pls. 85–88.

GRAVES, R. W., JR. & ELLISON, S. P., JR., 1941, Ordovician conodonts of the Marathon Basin, Texas: Univ. Missouri School Mines and Metallurgy, Bull., Tech. ser., v. 14, no. 2, 16 p., 3 pls.

GUNNELL, F. H., 1931, Conodonts from the Fort Scott Limestone of Missouri: Jour. Paleontology, v. 5, p. 244–252, pl. 9.

GUTSTADT, A. M., 1958, Upper Ordovician stratigraphy in eastern interior region: Am. Assoc. Petroleum Geologists, Bull., v. 42, p. 513–547.

HASS, W. H., 1952, Conodonts of the Barnett Formation of Texas: U. S. Geol. Survey, Prof. Paper 243-F, p. 69–94, pls. 14–16.

HALL, JAMES, 1851, Lower Silurian System. *In* Foster, J. W. & Whitney, J. D., Report on the geology of the Lake Superior Land District, Pt. 2, The iron region: Cong. Doc., 32d Cong., Special Sess., Senate Exec. Doc. 4, p. 140–166.

HINDE, GEORGE, 1879, On conodonts from the Chazy and Cincinnati Group of the Cambro-Silurian and from the Hamilton and Genesee-Shale division of the Devonian, in Canada and the United States: Geol. Soc. London, Quart. Jour., v. 35, p. 351–369, pls. 15–17.

KAY, G. M., 1928, Stratigraphy of the Decorah Formation: Jour. Geology, v. 37, p. 639–671.

——, 1935a, Ordovician System in the Upper Mississippi Valley: Kansas Geol. Soc., Ninth Ann. Field Conf., Guidebook, p. 281–295.

——, 1935b, Ordovician Stewartville-Dubuque problems: Jour. Geology, v. 43, p. 561–590.

KIRK, EDWIN, 1925, Notes on an early collection of Paleozoic Fossils from Ellesmereland: Am. Jour. Sci., 5th ser., v. 10, p. 445–447.

——, 1930, The Harding sandstone of Colorado: Am. Jour. Sci., 5th ser., v. 19, p. 456–466.

LINDSTRÖM, MAURITS, 1954, Conodonts from the lowermost Ordovician strata of south-central Sweden: Geol. Fören. Förhandl., Bd. 76, p. 517–604, pls. 2–10.

——, 1955, The conodonts described by A. R. Hadding, 1913: Jour. Paleontology, v. 29, p. 105–111, pl. 22.

——, 1957, Two Ordovician conodont faunas found with zonal graptolites: Geol. Fören. Förhandl., Bd. 79, p. 161–178, pl. 1.

—— & LAMONT, ARCHIE, 1957, Arenigian and Llandeilian cherts identified in the Southern Uplands of Scotland by means of conodonts, etc.: Edinburgh Geol. Soc., Trans., v. 17, p. 60–70, pl. 17.

MILLER, A. K., YOUNGQUIST, WALTER, & COLLINSON, CHARLES, 1954, Ordovician cephalopod fauna of Baffin Island: Geol. Soc. America, Mem. 62, p. 1–234, 63 pls.

PANDER, C. H., 1856, Monographie der fossilen Fische des silurischen Systems der russisch-baltischen Gouvernements: K. Akad. d. Wiss. St. Petersburg, 91 p., 9 pls.

RHODES, F. H. T., 1953, Some British Lower Paleozoic conodont faunas: Royal Soc. London, Philos. Trans., ser. B, v. 237, no. 647, p. 261–334, pls. 20–23.

——, 1954, The zoological affinities of the conodonts: Cambridge Philos. Soc., Biol. Rev., v. 29, p. 419–452.

——, 1955, The conodont fauna of the Keisley

Limestone: Geol. Soc. London, Quart. Jour., v. 111, p. 117–142, pls. 7–10.
—— & DINELEY, D. L., 1957, Devonian conodont faunas from southwest England: Jour. Paleontology, v. 31, p. 353–369, pls. 37,38.
—— & MÜLLER, K. J., 1956, The conodont genus *Prioniodus* and related forms: Jour. Paleontology, v. 30, p. 695–699.
—— & WINGARD, P. S., 1957, Chemical composition, microstructure, and affinities of the Neurodontiformes: Jour. Paleontology, v. 31, p. 448–454.
ROSS, R. J., JR., 1957, Ordovician fossils from wells in the Williston Basin, eastern Montana: U. S. Geol. Survey, Bull. 1021-M, p. 439–510, pls. 37–43.
SANNEMANN, DIETRICH, 1955, Ordovician und Oberdevon der beyrischen Fazies des Frankenwaldes nach Conodontenfunden: Neues Jahrb. Geologie u. Paläontologie, Abh., Bd. 102, p. 1–34, pls. 1–3.
SARDESON, F. W., 1907, Galena Series: Geol. Soc. America, Bull., v. 18. p. 179–194.
STAUFFER, C. R., 1935a, Conodonts of the Glenwood beds: Geol. Soc. America, Bull., v. 46, p. 125–168, pls. 9–12.
——, 1935b, The conodont fauna of the Decorah Shale (Ordovician): Jour. Paleontology, v. 9, p. 596–620, pls. 71–75.
——, 1938, Conodonts of the Olentangy Shale: Jour. Paleontology, v. 12, p. 411–443, pls. 48–53.
——, 1940, Conodonts from the Devonian and associated clays of Minnesota: Jour. Paleontology, v. 14, p. 417–435, pls. 58–60.
—— & THIEL, G. A., 1941, The Paleozoic and related rocks of southeastern Minnesota: Minnesota Geol. Survey, Bull. 29, 261 p.
STONE, G. L., 1958, Upper Bighorn Conodonts from Wyoming: State Univ. Iowa (Unpublished M.S. thesis).
STROTHMANN, F. H., 1940, Conodonts from the Kimmswick of eastern Missouri: Univ. Missouri (unpublished M.S. thesis).
SWEET, W. C., 1955, Conodonts from the Harding Formation (Middle Ordovician) of Colorado: Jour. Paleontology, v. 29, p. 226–262, pls. 27–29.
—— & MILLER, A. K., 1958, Ordovician cephalopods from Cornwallis and Little Cornwallis islands, District of Franklin, Northwest Territories: Geol. Survey of Canada, Bull. 38, 86 p., 8 pls.
TWENHOFEL, W. H. et al., 1954, Correlation of the Ordovician formations of North America: Geol. Soc. America, Bull., v. 65, p. 247–298, pl. 1.
ULRICH, E. O., 1911a, Bearing of the Paleozoic Bryozoa on paleogeography: Geol. Soc. America, Bull., v. 22, p. 252–257.
——, 1911b, Revision of the Paleozoic systems: Geol. Soc. America, Bull., v. 22, p. 281–680, pls. 25–29.
—— & BASSLER, R. S., 1926, A classification of the toothlike fossils, conodonts, with descriptions of American Devonian and Mississippian species: U. S. Natl. Mus., Proc., v. 68, art. 12, p. 1–63, pls. 1–11.
WEISS, M. P., 1955, Some Ordovician brachiopods from Minnesota and their stratigraphic relations: Jour. Paleontology, v. 29, p. 759–775, pls. 69–72.
——, 1957, Upper Middle Ordovician stratigraphy of Fillmore County, Minnesota: Geol. Soc. America, Bull., v. 68, p. 1027–1062, 5 pls.
WINCHELL, N. H. & ULRICH, E. O., 1897, The Geology of Minnesota, v. 3, Paleontology, 1081 p., 82 pls.
YOUNGQUIST, W. L. & CULLISON, J. S., 1946, The conodont fauna of the Ordovician Dutchtown formation of Missouri: Jour. Paleontology, v. 20, p. 579–590, pls. 89–90.

EXPLANATION OF PLATE 41

FIGS. *1,2—Rhynchognathus aborodentata* Ethington, n. sp. *1*, Inner lateral view; and *2*, outer lateral view, both ×100, Dubuque Member, Locality 8, holotype (10046).

3,4—Rhynchognathus typica Ethington, n. sp., ×100, Dubuque Member, Locality 8, holotype (10045).

5—Icriodella acuta Rhodes, ×60, Dubuque Member, Locality 8, hypotype (10028).

6—Trichonodella inclinata Rhodes, ×120, Dubuque Member, Locality 10, hypotype (10054).

7,8—Trichonodella flexa Rhodes, ×50. *7*, Posterior view; and *8*, anterior view. Dubuque Member, Locality 10, hypotype (10053).

9—Trichonodella insolita Ethington, n. sp., ×100, Dubuque Member, Locality 10, holotype (10051).

10,11—Trichonodella exacta Ethington, n. sp. *10*, Postero-lateral view; *11*, anterior view, both ×50, Dubuque Member, Locality 10, holotype (10052).

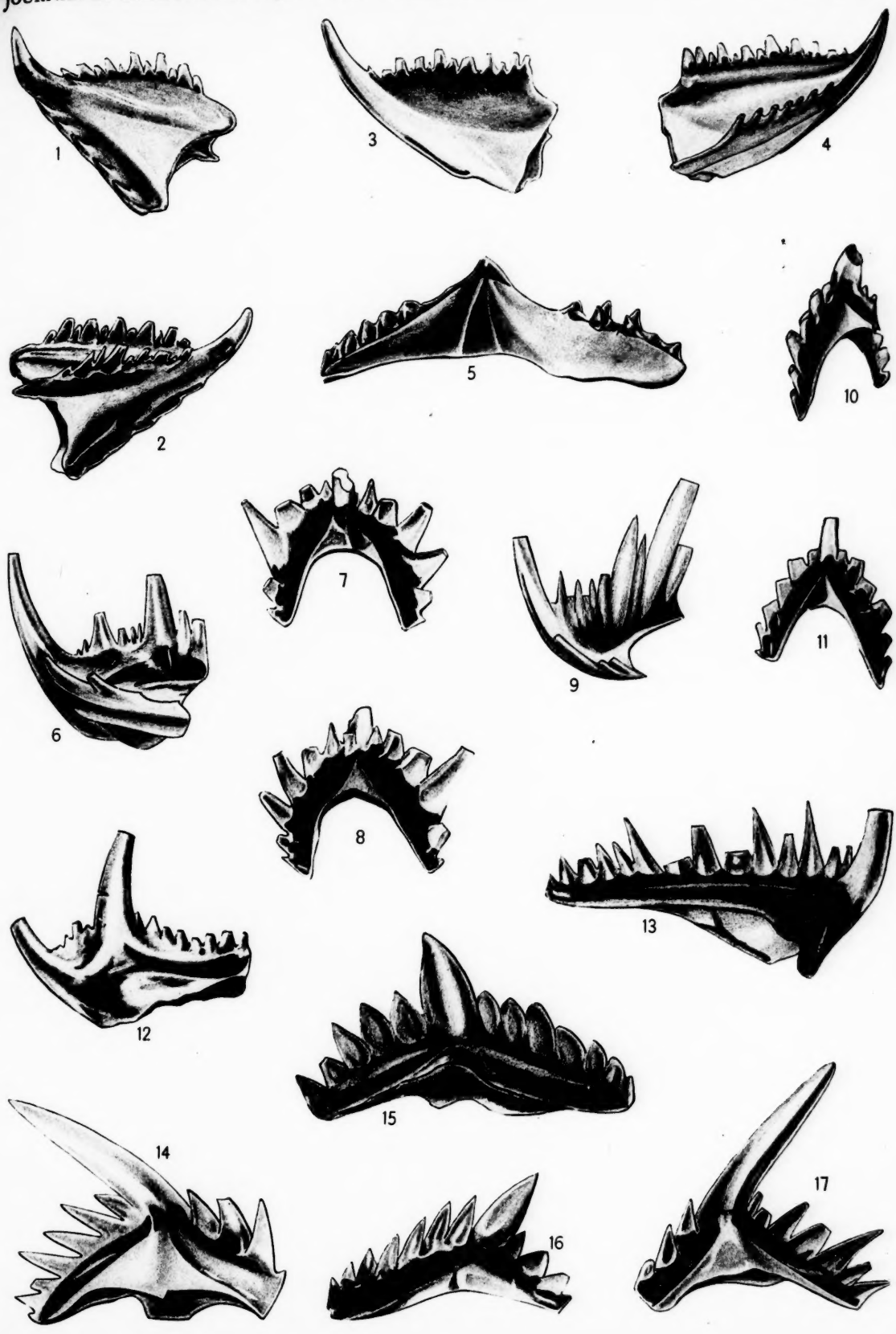
12—Phragmodus undatus Branson & Mehl, ×60, Prosser Member, Locality 4, hypotype (10044).

13—Subcordylodus delicatus (Branson & Mehl), ×50, Dubuque Member, Locality 7, hypotype (10049).

14—Ozarkodina macrodentata Graves & Ellison, ×90, Prosser Member, Locality 3, hypotype (10038).

15,16—Ozarkodina concinna Stauffer. *15*, Prosser Member, Locality 3, hypotype (10035); and *16*, Dubuque Member, Locality 7, hypotype (10036), both ×60.

17—Ozarkodina delecta Stauffer, ×60, Dubuque Member, Locality 2, hypotype (10037).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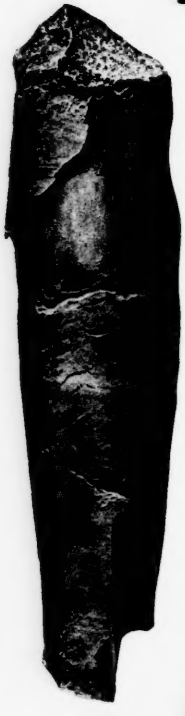

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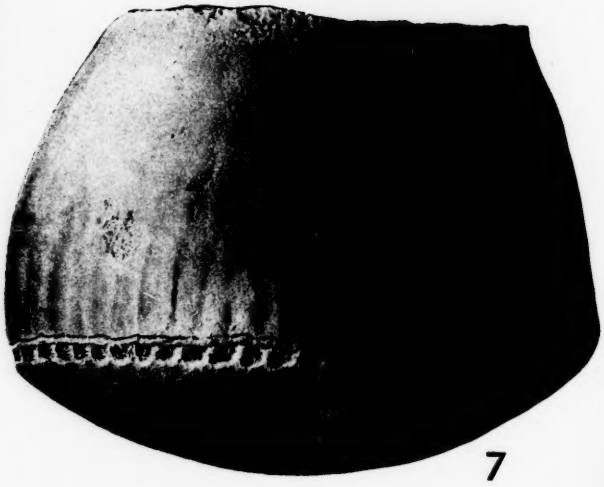

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JOURNAL OF PALEONTOLOGY, V. 33, NO. 2, P. 293–304, PLS. 42–43, 1 TEXT-FIG., MARCH 1959

MUSCLE-ATTACHMENT IMPRESSIONS IN SOME PALEOZOIC NAUTILOID CEPHALOPODS

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ABSTRACT—Muscle-attachment impressions are described for the first time from representatives of the nautiloid suborders Oncoceratina (*Oncoceras* sp., *Beloitoceras* sp., *Diestoceras* sp.), Ascoceratina (*Billingsites deformis* (Eichwald)?), Discosorina (*Parryoceras euchari* Sweet & Miller), and Rutoceratina (*Metacoceras* sp.), and notes concerning the probable configuration of such impressions in certain Paleozoic Barrandeoceratina (*Charactoceras?*) and Triassic Lyroceratina (*Proclydonautilus ursensis* Smith) are included. Muscle-attachment impressions are not known in the Endoceratina and Actinoceratina; in known Ellesmeroceratina, Michelinoceratina, and secondarily straight Tarphyceratina (Lituitidae) the retractors were attached dorsally ("dorsomyarian"), whereas in described Barrandeoceratina, coiled Tarphyceratina, Ascoceratina, Oncoceratina, and Discosorina, these muscles were attached ventrally ("ventromyarian"). Described Rutoceratina, Nautilina, Solenochilina, and Lyroceratina are similar in that the retractors were attached laterally ("pleuromyarian"). In several cases, similar attachment patterns suggest adaptive convergence, rather than relationship, and their taxonomic significance is thereby reduced.

INTRODUCTION

ONLY a few contributions have been made to our knowledge of the configuration and arrangement of the muscle-attachment impressions in fossil cephalopods, primarily, it seems, because well preserved specimens exhibiting these features are not particularly common and most investigators have apparently attached only minor systematic importance to them. In 1957, Mutvei prepared a summary of the literature concerning muscle-attachment impressions in fossil nautiloids and, in the same work, included descriptions and illutrations of several additional examples found by him in a collection of well preserved specimens from the Ordovician and Silurian of Sweden. Other forms are described by Miller (1951, p. 38, pl. 5, fig. 1) and illustrated by Kummel (1953, pl. 2, figs. 11,12; pl. 11, figs. 1,2). In addition to these reports, Foerste (1930) seems to have interpreted the "basal zone" of at least one group of Paleozoic nautiloids as part of the muscle-attachment ring or "annulus," even though he apparently did not attach any particular taxonomic significance to this feature.

Crick (1898a) described the muscle-

EXPLANATION OF PLATE 42

FIG. *1*—*Billingsites deformis* (Eichwald)? Ventral view, ×1, of a specimen from the Upper Ordovician Cape Phillips formation, on the eastern part of Little Cornwallis Island, Canadian Arctic Archipelago. Geol. Surv. Canada, No. 12231.

2,3—*Parryoceras euchari* Sweet & Miller. Ventral views, ×1, of the holotype and paratype of this species. Both specimens from the Upper Ordovician Cape Phillips formation, Marshall peninsula, Cornwallis Island, Canadian Arctic Archipelago. Geol. Surv. Canada Nos. 12243, 12244.

4—*Beloitoceras* sp. Ventral view, ×1.5, of a specimen from the Upper Ordovician Cape Phillips formation, eastern part of Little Cornwallis Island, Canadian Arctic Archipelago. Geol. Surv. Canada, No. 12235.

5—*Oncoceras* sp. Ventral view, ×1.5, of a specimen from the Upper Ordovician Cape Phillips formation, eastern part of Little Cornwallis Island, Canadian Arctic Archipelago. Geol. Surv. Canada, No. 12233.

6,7—*Diestoceras* sp. Ventral and lateral views, ×1, of a large body chamber showing a well preserved annular elevation. Upper Ordovician Boda limestone, Osmundberget, Dalarna, Sweden. Univ. Uppsala, Paleontological Institute, No. D739.

attachment impressions in several ammonoid species, chosen from a large collection to exhibit these features in a variety of conch forms, and concluded his remarks by pointing out (p. 108) that ". . . indications of the muscular attachment of the Ammonoid animal, instead of being rare, seem to be fairly common." Nevertheless, Arkell et al. (1957, p. L81) remark that ammonoids ". . . very rarely retain vague muscle scars," and they seem to attach no particular importance, taxonomically or otherwise, to the forms described by Crick and others.

Because so little is known about muscle-attachment impressions in fossil cephalopods, the several specimens in collections at hand that exhibit these features are of more than ordinary significance and merit detailed description. These specimens, which form the material upon which the present report is based, were assembled over a period of several years and from a number of different localities. Several well preserved specimens were found in collections made by Dr. Raymond Thorsteinsson, of the Geological Survey of Canada, from Upper Ordovician strata on Cornwallis Island in the Canadian Arctic Archipelago. Professor C. H. Summerson, of The Ohio State University, supplied a fragmentary *Metacoceras* from the Pennsylvanian of Kentucky, and Professor Per Thorslund, of Uppsala University, Sweden, sent to the writer on loan a large collection of Upper Ordovician nautiloids, including several that show muscle-attachment impressions, from the Boda limestone of Sweden. The latter were collected largely by the late Professor Elsa Warburg, of Uppsala. The writer is indebted to all these men for making their collections available to him for study, and to Mr. Harry Mutvei, of the Naturhistoriska Riksmuseet, Stockholm, for discussion of problems pertaining to the muscle-impressions in nautiloids. Illustrations accompanying this paper were prepared by the writer and financed by a liberal grant from the Graduate School of The Ohio State University.

MUSCLES AND MUSCLE-ATTACHMENT IMPRESSIONS IN NAUTILUS

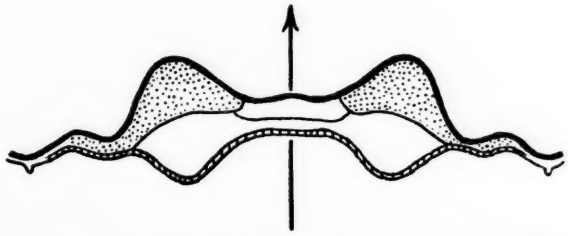
The musculature and muscle-attachment impressions in *Nautilus*, the only living tetrabranchiate cephalopod, have been adequately described in several places (Owen, 1832; Waagen, 1870; Dewitz, 1879a, 1879b, 1880; Schröder, 1881; Appellöf, 1893; Griffin, 1900; Willey, 1902; Miller, Dunbar, & Condra, 1933; Mugglin, 1939; Flower, 1946; Miller, 1947; Stenzel, 1952; Mutvei, 1957), hence it seems unnecessary to review these discussions in any detail here. A summary of the observations referred to is appropriate, however, so that the structures to be described may be understood in relation to presumably comparable features in *Nautilus*. It should perhaps be pointed out that all of these reports are in essential agreement as to the structure and relationship of the principal musles in *Nautilus* and their areas of functional attachment on the shell; however, the several authors use different terminology and, to a minor degree, their interpretations are at variance with one another. For these reasons, the following discussion is based on the recent work of Stenzel (1952) and Mutvei (1957).

In *Nautilus*, a complex of three different muscle systems is attached, somewhat indirectly, to the inner side of the shell along a transverse sinuous ring-shaped elevation near the adapical end of the body chamber. This attachment area and the ring of muscles attached to it are referred to as the "annulus" by most writers; however, the designation "annular elevation" (Mutvei, 1957) for the shell-attachment zones seems preferable and is used in this report. The term "annulus" is restricted to the ring-shaped muscle-complex attached to the shell along the annular elevation.

The most conspicuous of the three muscle systems attached to the annular elevation includes a pair of powerful retractor ("shell") muscles, about 5 cm. long, each of which is anchored at its adoral end to a short process on the internal cephalic cartilage. These muscles diverge adapically in the form of a V (as viewed from above) to form the sides and part of the ventral wall of the body within the pallial cavity (Stenzel, 1952). Each retractor is attached, by means of a transversely fibrous epithelial layer, to broad subtriangular antero-lateral expansions and somewhat narrower dorsolateral portions of the annular elevation (stippled area of Text-fig. 1). The weakly developed longitudinal mantle muscles of *Nautilus* appear to be

attached, in much the same fashion as the retractor muscles, to a narrow zone along the adapertural edge of the annular elevation (solid black area of Text-fig. 1), whereas a third system of subepithelial muscle tissue is functionally attached along the thin sinuous adapical edge of the elevation, coincident with, or only slightly orad of the youngest suture of the phragmocone (cross-lined area of Text-fig. 1).

Mutvei (1957) terms the transverse annular zone of epithelium that includes the termini of the mantle and retractor muscles "epithelial zone I", and refers to that portion of the annular elevation along which this band is attached as "conchial zone I". In like manner, Mutvei terms the posterior band of whitish mantle tissue, containing the termini of the subepithelial muscles, "epithelial zone II," and applies the designation "conchial zone II" to the adapical margin of the annular elevation to which this band is attached. These terms seem free from positive objection and are perhaps more precise than the older denomination, "annulus", employed previously for both the epithelial and conchial zones. Parts of epithelial zones I and II have been regarded as forming a *dorsal aponeurotic band;* the adapertural edge of the annulus between the lateral expansions of epithelial zone I makes up the *antero-ventral aponeurotic band* of several authors; and the adapical margin of the annulus has been termed the *postero-ventral aponeurotic band.* However, since there is apparently some question (Mutvei, 1957) as to whether or not these tissue bands are actually aponeuroses in *Nautilus*, it seems best to avoid the use of such terms in the description of fossil forms.



TEXT-FIG. *1*—Diagrammatic representation of the annular elevation of *Nautilus*, approximately ×½. Longitudinal mantle muscles attached along heavy black line; retractor-muscles attached to stippled areas; subepithelial muscles attached along cross-lined area. Heavy black, and stippled areas composed conchial zone I; cross-lined area represents conchial zone II. (After Mutvei, 1957.)

MUSCLE-ATTACHMENT IMPRESSIONS IN FOSSIL NAUTILOIDS

At the present time, about 550 genera and approximately 3,000 species of nautiloid cephalopods are recognized. These are distributed rather unevenly among 82 families which, in turn, are grouped together in 13 suborders. It may be of interest, then, to note that the configuration of the annular elevation, or part of it, is known from representatives of only 31 genera, belonging in 20 or 22 of the 82 currently recognized families, and distributed among 11 of the 13 suborders. This tabulation, which includes the several specimens described in the present contribution, but does not include the many phragmoceroids described by Foerste (1930), emphasizes our lack of knowledge about the structure, position, relationship, and attachment patterns of muscles in fossil nautiloids, and suggests that we must know a good deal more about the annular elevation in fossil cephalopods before this feature can be accorded any particular significance taxonomically.

Ellesmeroceratina.—This suborder includes 11 families of primitive nautiloids, to which some 280 named species are referred. Muscle-attachment impressions have been described (Dewitz, 1879a; Schröder, 1881; Mutvei, 1957) from representatives of only one species, *Baltoceras burchardi* (Dewitz). *B. burchardi* has a relatively large, marginal or submarginal siphuncle and a virtually straight conch that may be slightly curved

apically toward the siphuncular (ventral?) side. Presumably, this indicates that the conch is slightly endogastric. The adapical and adoral edges of the annular elevation are close together and parallel to the adoral suture on the ventral and ventrolateral sides of the body chamber, but the adoral edge of the elevation swings broadly toward the aperture dorsolaterally, forming a low, broad salient on the dorsum. This salient apparently represents, in large part at least, the locus of attachment for the retractor muscles.

Endoceratina and Actinoceratina.—Muscle-attachment impressions have not been reported from the many known representatives of the suborders Endoceratina and Actinoceratina, both of which find their origin in late Lower Ordovician members of the Ellesmeroceratina.

Michelinoceratina.—The suborder Michelinoceratina includes a host of straight or slightly curved nautiloids characterized, in general, by a primitively tubular, but secondarily cyrtochoanitic siphuncle. Early representatives of this suborder are closely similar to contemporaneous and presumably ancestral species included in the Baltoceratidae (Ellesmeroceratina), but differ from the baltoceratids in that the connecting rings are thin and apparently homogeneous, rather than thickened. To the best of the writer's knowledge, the configuration of the annular elevation is known from representatives of only five of the several hundred named species of the Michelinoceratina, *"Geisonoceras" scabridium* (Angelin), *"Orthoceras" angulatum* Wahlenberg, *Orthoceros regulare* (Schlotheim), *Lyecoceras gotlandense* Mutvei, and *Lyecoceras longistriatum* Mutvei. Existing information with regard to the types of the first two species listed is inadequate to suggest their familial or even their proper generic reference. It is distinctly possible, however, that *"G." scabridium* is, indeed, a *Geisonoceras; "O." angulatum* is reminiscent of longitudinally fluted orthoceracones referred by many writers to *Kionoceras. Lyecoceras gotlandense* and *L. longistriatum* represent a generic category erected by Mutvei (1957) for slightly depressed annulated endogastric cyrtoceracones from the lower Ludlovian Hemse Group, on Gotland, Sweden. *Lyecoceras* apparently has an eccentric orthochoanitic siphuncle located somewhat closer to the convex (dorsal) side of the conch than to the concave (ventral) side. Sutures in both known species form a broad lobe on the dorsal and dorsolateral portions of the conch, and a low rounded saddle on the venter. The apertural margin is said to bear a hyponomic sinus on the concave side of the conch and a well defined septal furrow on the convex side. It should be noted that there is considerable external similarity between the two known species of *Lyecoceras* and Barrande's *Cyrtoceras cognatum* and *C. pergratum*, both of which were referred by Foerste (1936) to the genus *Calocyrtoceras*. The presence or absence of a hyponomic sinus cannot be determined from Barrande's illustrations (1866, pl. 199, fig. 35–45) of *C. cognatum*, but there is a suggestion of such a feature on the concave side of the conch in one of his illustrations of *C. pergratum* (1866, pl. 199, fig. 7), a species closely related to *C. cognatum*. Foerste (1936) distinguished the genus *Cyrtocycloceras* from *Calocyrtoceras* by the fact that no longitudinal striation occurs on the shell of typical representatives of the former, whereas the types of the latter bear prominent longitudinal striae. The writer regards differences of this character as dubious grounds for generic subdivision, insofar, at least, as other features of these two genera are almost precisely similar. *Lyecoceras* is reminiscent externally of both *Calocyrtoceras* and *Cyrtocycloceras*, the types of which are also of about the same age. It seems distinctly possible, therefore, that *Lyecoceras*, *Calocyrtoceras*, and *Cyrtocycloceras* are all names for virtually the same group of species and that *Calocyrtoceras* and *Lyecoceras* should be suppressed in favor of *Cyrtocycloceras*, which is the oldest available name for the group. The writer hesitates to do this, however, for he has not been able to make direct comparisons between the several types involved. It does seem clear, however, that the species at present distributed among these three genera belong in the same family, for which Flower (*in* Flower & Kummel, 1950) proposed the name Paraphragmitidae.

In all of the michelinoceratinid species enumerated above, the elements of the annular elevation are similar in distribution to those of *Baltoceras burchardi;* that is, the ex-

panded portion presumed to be the locus of attachment of the retractor muscles is situated on the dorsal side of the conch. In all these species, however, the expanded dorsal portion of the annular elevation is distinctly bifid, being separated into two more or less distinct portions by an adapically-directed, mid-dorsal notch in the adoral edge of the elevation.

Ascoceratina.—This suborder includes a group of bizarre early Paleozoic nautiloids with essentially straight or slightly cyrtoceraconic conchs, and siphuncles characterized by planoconvex segments that become broadly expanded in mature camerae. Furthermore, natural truncation of the early-formed portions of the conch seems to have taken place in virtually all known representatives of the suborder and, in more advanced members, the adoral few camerae were altered in shape so that they came to lie above (rather than behind) the animal's body. Insofar as the writer is aware, no previous mention has been made of the annular elevation in any species referable to this suborder.

One of the ascoceratinids in Upper Ordovician collections available to the writer shows the annular elevation, or portions of it, and, for that reason, this specimen merits somewhat more detailed description than it it has received previously (Sweet & Miller, 1957). The specimen illustrated by figure 1, on Plate 42, is a representative of the family Ascoceratidae, and has been tentatively identified (Sweet & Miller, *loc. cit.*) as *Billingsites deformis* (Eichwald)?. It is not necessary to repeat a detailed description of this form here, but it should be pointed out that further preparation of this specimen has disclosed faint but well preserved traces of the annular elevation. On the dorsum and the sides of the specimen, the elevation consists of a narrow raised band, parallel to and immediately orad of the last-formed sigmoidal suture. On the venter, however, the raised adapical edge of the annular elevation remains parallel to the adoral suture, whereas the ridge-like adoral edge of the elevation swings prominently forward to form a distinct ventral salient, subdivided by a mid-ventral notch into two subequal lobate portions. Presumably, these two ventral elements of the annular elevation represent the areas to which the retractor muscles were affixed. It should also be noted that the internal mold bears a distinct mid-ventral ridge, indicating the presence on the inner surface of the shell itself of a longitudinal mid-ventral groove. This is almost certainly an expression of the conchial furrow, a structure known to be located in the mid-ventral interior of the nautiloid conch.

Oncoceratina.—Earlier concepts of the suborder Oncoceratina (Flower, *in* Flower & Kummel, 1950) have recently been revised (Flower, *in* Flower & Teichert, 1957) so that this group is now conceived to include, for the most part, compressed exogastric cyrtoceracones and brevicones with ventral siphuncles, the segments of which are tubular in primitive forms, but expanded in later, more advanced species. In four of the 12 familes currently included in the Oncoceratina, the siphuncle is empty, whereas in the remaining eight, it contains specialized actinosiphonate deposits. Although the Oncoceratina includes some 120 genera, to which several hundred species have been referred, the writer is unaware of any previous description of muscle-attachment impressions, as such, from a valid representative of any of these species. Several such specimens occur, however, in collections of the Geological Survey of Canada from the Upper Ordovician of Cornwallis Island, in the Canadian Arctic Archipelago. A ventral view of one of these specimens, described by Sweet & Miller as *Oncoceras* sp., is shown by figure 5, Plate 42 of the present report. From this illustration, it can be seen that the adapical and adoral edges of the elevation are close together laterally (and, presumably, dorsally), being separated only by a narrow "basal zone," consisting of a transverse row of quadrangular loculi immediately adjacent to the adapical extremity of the body chamber. On the venter, however, the adoral edge of the elevation projects broadly toward the aperture to outline a small, but nevertheless distinct retractor-attachment area, divided into two elements by a broadly V-shaped, mid-ventral notch. The transversely subelliptical areas included between conchial zones I and II on the venter are "pitted," indicating that the surfaces of the slightly raised bosses of shell material were similarly pitted or nodose. Such elevational

irregularities occur also in illustrated representatives of *Discoceras angulatum* (Saemann) and *"Geisonoceras" scabridium* (Angelin) (Mutvei, 1957, text-fig. 12,15), and longitudinally lineated elevations are shown by Mutvei (1957, text-fig. 13,16,17) in *Lyecoceras?* sp., *Lyecoceras gotlandense*, and *"Orthoceras" angulatum* Wahlenberg.

A ventral view of an oncoceratid identified as *Beloitoceras* sp. by Sweet & Miller (1957, p. 46, pl. VI, fig. 5) is shown by figure 4, Plate 42. The annular elevation in this form consists of a narrow dorsal and lateral band, enclosing the "basal zone," and a bifid ventral salient similar in location and general proportions to that shown by *Oncoceras* sp., described above. As in *Oncoceras*, it appears that the retractor muscles were functionally attached to the ventral side of the shell in *Beloitoceras*.

A large, incomplete internal mold, representing the body chamber of a *Diestoceras*, is shown by figures 6 and 7 on Plate 42. This specimen, which was collected from the Upper Ordovician Boda limestone, at Osmundberget, Dalarna, Sweden, clearly exhibits a virtually complete annular elevation. This consisted, on the original shell, of a slightly raised transverse band, some 5 mm. wide, at the adapical extremity of the body chamber, marked adorally by a narrow incised serrate groove separated from the adoral septum by a row of subquadrangular nodes or bosses. Ventrally, the adoral edge of the annular elevation is produced into a broad adapically convex sinus, and the zone of subquadrangular nodes is replaced by a pair of surficially tuberculated, adapically convex bosses, presumably representing the loci of retractor-muscle attachment. Dorsally, the adoral edge of the annular elevation forms a slight broad salient, separated from a "basal zone" of markedly reduced width by a second incised line. This specimen of *Diestoceras* is similar to *Oncoceras* and *Beloitoceras* in the gross distribution of the elements of the muscle-attachment ring, but differs from them in that the presumed loci of retractor-attachment are produced toward or onto the last-formed septum, rather than adorally along the walls of the body chamber. This is perhaps a result of the greatly shortened, contracted body chamber of *Diestoceras*.

Discosorina.—The suborder Discosorina includes a group of some 345 species, distributed at present among about 42 genera. These genera are grouped (Flower, *in* Flower & Teichert, 1957) into 8 families, and are thought to represent a stock derived, independently of other nautiloids, from early Ordovician Plectronoceratidae (Ellesmeroceratina). To the best of the writer's knowledge, the muscle-attachment impressions of this group have not previously been described, as such, although Foerste (1930) appears to have regarded the "basal zone" in a majority of the discosorinid species he described as some part of the "annulus", or annular elevation. Two specimens of *Parryoceras euchari* Sweet & Miller in collections of the Geological Survey of Canada, show clearly the relationship between the "basal zone" and the retractor-muscle attachment areas, and, for that reason, they merit additional discussion here.

Parryoceras euchari is an endogastric cyrtoceracone referred by Sweet & Miller (1957) to the family Cyrtogomphoceratidae. The adapical extremity of the body chamber on both the holotype and the single known paratype of this species is marked (Pl. 42, figs. 2,3) by a transverse row of quadrangular depressions (a "basal zone"), which represents a similarly transverse, nodose, or tuberculated band of shell material on the inner portion of the original shell. The adoral and adapical edges of the "basal zone" are marked by fine irregularly serrate raised lines that are interpreted to mark the adoral and adapical edges of the annular elevation. On the ventral side of the conch, the quadrangular depressions of the "basal zone" are replaced by two transversely subelliptical areas, representing surficially nodose ventral bosses of shell material in the original shell. These ventral impressions seem clearly to represent the areas of retractor-attachment.

It is reasonable to presume, as Foerste seems to have done, that the "basal zone", so characteristically developed in many, if not most Discosorina, represents some part of the annular elevation. Unfortunately, little attention seems to have been paid this feature in the past, and it is not possible to make direct comparisons of the material at hand with other Discosorina.

Tarphyceratina.—Included in this sub-

order are four families of cyrtoceraconic, or variously coiled nautiloids, all similar in that the connecting rings of the siphuncle are thick and complex and the siphuncle as a whole tends, at least in primitive forms (and in the early parts of advanced forms), to be located ventrad of the center of the conch. The four families of Tarphyceratina (Basslerocerati dae, Tarphyceratidae, Trocholitidae, and Lituitidae) include some 170 species, distributed among about 42 named genera. The configuration of the annular elevation is not yet known in members of the cyrtoceraconic Basslerocerati dae, but it has been reported from representatives of *Estonioceras impressum* (Hyatt), *E. perforatum* Schröder, *E. imperfectum* (Quenstedt), and *Planctoceras falcatum* (Schlotheim), which probably belong either in the Tarphyceratidae or in an as yet unnamed tarphyceratinid family; from *Discoceras angulatum* (Saemann), and *Discoceras* sp., of the Trocholitidae (Mutvei, 1957); and from *Lituites procerus* Remelé (Noetling, 1882) and perhaps from *Rhynchorthoceras helgoeyense* Sweet (Sweet, 1958), representatives of the Lituitidae.

In known tarphyceratid and trocholitid species, the expanded portion of the annular elevation thought to be the site of attachment for the retractor muscles is located on the ventral side of the conch (Mutvei, 1957), but in the two known lituitids, this retractor-attachment area is dorsal in position, having perhaps migrated to such a position as the mature conch uncoiled.

Barrandeoceratina.—Included in this suborder are six families of coiled nautiloids similar to, and almost certainly derived from the Tarphyceratina. Representatives of this suborder are distinguished from the Tarphyceratina, however, by the fact that the siphuncle is primitively tubular, central to ventral in position, and composed of thin, homogeneous connecting rings. Present knowledge concerning the configuration of the annular elevation in the Basslerocerati na is based upon the several upper Ordovician specimens described by Mutvei (1957) as *Uranoceras? longitudinale* (Angelin). Although the generic and familial reference of these specimens is open to question, there seems to be little doubt but that they belong in the Barrandeoceratina as that group is presently understood, and the writer is inclined to suspect that they represent an undescribed genus of Apsidoceratidae, rather than belonging in *Uranoceras* or the Uranoceratidae, a dominantly Silurian group. In all of Mutvei's specimens, the expanded areas of retractor attachment are ventral in position; on one of them, a well marked septal furrow is shown on the dorsal side of the conch.

The same collections from the Upper Ordovician Boda limestone of Sweden that yielded the representatives of *Uranoceras? longitudinale* described by Mutvei, also contain several undescribed specimens of *Charactoceras* (Apsidoceratidae), one of which exhibits the lateral and ventrolateral portions of the annular elevation. In this specimen, as in the ones described by Mutvei, the expanded retactor-muscle scars seem to be ventral in position. A similar configuration of the annular elevation is suggested by an incomplete structure at the adapical end of the body chamber of a large apsidoceratid collected by the writer from the Upper Ordovician Gastropod limestone (substage 5a), at Stavnestangen, Ringerike, Norway. This specimen is incomplete, and its generic affinities are questionable; however, it seems to be intermediate in form between Mutvei's *Uranoceras? longitudinale* and the Boda limestone *Charactoceras.* It bears a well marked septal furrow on the concave, slightly impressed dorsal side; the adapical and adoral margins of the annular elevation are subparallel laterally, but near the ventrolateral margins of the conch, the adoral margin appears to swing orad, indicating the presence on the venter of a broadly expanded retractor-muscle attachment area.

Rutoceratina.—The suborder Rutoceratina, which includes a rather large and superficially heterogeneous assemblage of middle and late Paleozoic and early Mesozoic (Triassic) nautiloids, had its inception in the Devonian, and appears to be connected genetically with the Oncoceratina. The Rutoceratidae, the ancestral radical of this suborder, formed broad-whorled conchs that were, for the most part, gyroceraconic in plan and rather highly ornamented by frills, wings, nodes, and spines. However, both cyrtoceracones and trochoceracones occur in the Rutoceratidae, and the conchs of some

species appear to have been virtually straight. From this family, or its derivatives, there developed several more or less close-coiled groups, referred to the families Tetragonoceratidae, Koninckioceratidae, and Tainoceratidae. The Tetragonoceratidae is a Devonian family; the Koninckioceratidae is first recognized in the Mississippian and continued until the end of the Paleozoic; the Tainoceratidae also appears to have roots in the Mississippian, but it is well represented in the Triassic.

The configuration of the annular elevation has been reported or figured previously from representatives only of the Tainoceratidae: a Triassic species of *Germanonautilus* (Mojsisovics, 1882), *Metacoceras* (*Mojsvaroceras*) *turneri* (Kummel, 1953, pl. 2, figs. 11,12) from the Upper Triassic of California, and a species of *Pleuronautilus* (Mojsisovics, 1873). In addition to these, a specimen at hand, identified only as *Metacoceras* sp., exhibits a complete annular elevation, which appears to be typical of the group to which it belongs.

The last named specimen, collected from the Middle Pennsylvanian Kendrick shale of eastern Kentucky by Professor C. H. Summerson, is an incomplete internal mold of an immature individual. As can be seen from the four views of this specimen on Plate 43 it is some 68 mm. in length, and represents parts of seven camerae of the phragmocone and the adjacent adapical portion of the body chamber. The outer whorl, of which this specimen is a fragment, is 23 mm. high and 33 mm. wide at the adapical end of the segment preserved. The venter is broadly convex; the lateral zones are flat or slightly concave and meet the venter at virtually a right angle. The dorsolateral zones are faintly convex and rather abruptly set-off from the lateral zones, which they join at an angle of about 135°. The dorsum is broadly concave and separated from the dorsolateral zones by narrow acutely rounded umbilical shoulders. Approximately six camerae occur in a ventral distance equivalent to the maximum width (39.5 mm.) of the phragmocone. Sutures are sinuous, forming broad ventral lobes, asymmetrical ventrolateral saddles, and slight lateral lobes, separated from faint dorsolateral lobes by low asymmetrical saddles. The dorsum bears deep broadly V-shaped lobes, separated from the dorsolateral lobes by prominently rounded saddles on the umbilical shoulders. A longitudinal row of low, broad nodes occurs on the ventrolateral corners of the internal mold, suggesting that a similar, but perhaps somewhat more prominent series of ornaments occupied that position on the shell. The venter is marked by a faint, longitudinal ridge, indicating the position of the conchial furrow.

On the dorsum of the specimen in question, the annular elevation consists of a narrow V-shaped band, 2 mm. wide, parallel to the adoral suture of the phragmocone. The adapical margin of this band is parallel to the suture for the full circumference of the conch, but, dorsolaterally, the adoral edge of the elevation is produced orad and, in the lateral zones, it describes broad asymmetrical salients, projecting some 10 mm. beyond the adoral suture and outlining transversely subelliptical areas presumed to be the loci of retractor-muscle attachment. On the venter, the annular elevation is represented by a slightly sinuous band, some 3 mm. in maximum width, subdivided into two narrowly elliptical areas by a slight mid-ventral notch. It should also be noted that, in the lateral zones, there is a faint transverse ridge separating the elliptical areas of retractor attachment from the posterior margin of the elevation. As in *Nautilus*, this line probably represents the posterior margin of the retractor-attachment area. It merges both ventrally and dorsolaterally with the anterior edge of the elevation.

Although direct connections have not yet been established, it is probable that the coiled suborders Solenochilina, Lyroceratina, and Nautilina developed from the Rutoceratina rather than from species in the dominantly coiled suborders Barrandeoceratina and Tarphyceratina. All three suborders are characterized by coiled conchs and the configuration of the annular elevation is known from at least a few representatives of each suborder. Foord & Crick (1890) published the only figures and descriptions of which the writer is aware of the annular elevation in *Solenochilus*, the typical (and sole) genus of the Solenochilidae and Solenochilina. The writer is unaware of any published description of the muscle-attach-

ment configuration in a representative of the Lyroceratina, but in a recent work by Kummel (1953, pl. 11, figs. 1,2) there is an illustration that appears to show at least the lateral portion of the elevation in *Proclydonautilus ursensis* Smith, an Upper Triassic species of the family Clydonautilidae, from the Hosselkus limestone of California. In the Nautilina, the muscle-attachment arrangement is known in *Aphelaeceras*, *Cenoceras*, *Cimomia*, *Eutrephoceras*, *Grypoceras*, *Nautilus*, *Pseudaganides*, *Syringoceras*, and *Vestinautilus* (Mojsisovics, 1873, 1882; Foord & Crick, 1889, 1890; Crick, 1898; Foord, 1900; Loesch, 1914; Miller, 1951; Mutvei, 1957). In known representatives of all three suborders, the expanded, subelliptical or subtriangular areas of retractor attachment occupy a lateral position on the annular elevation and the gross shape and arrangement of conchial zones I and II appear to be much the same as in *Nautilus*.

TAXONOMIC SIGNIFICANCE OF THE ANNULAR ELEVATION IN FOSSIL NAUTILOIDS

In a recent paper, Mutvei (1957, p. 232) states that ". . . in spite of the fact that the annular elevation is so far known only in a small number of fossil nautiloids, it is already possible to foresee its great importance to nautiloid taxonomy." Certainly, it is true that all features providing information about the organization of the animal should be carefully evaluated in a search for the phylogenetic relationships that zoological classification attempts to mirror. Indeed, a careful study of the arrangement of the muscles in fossil nautiloids might yield much valuable information as to the anatomy of these animals were it not for the fact that traces of muscle-attachment impressions are not commonly preserved.

Mutvei (1957) points out that known muscle-attachment impressions in fossil cephalopods can be divided into three categories: (1) a group, here termed "dorsomyarian", in which the loci of retractor-muscle attachment are dorsal in position, (2) a category, here designated "pleuromyarian", in which the retractors are functionally attached to the lateral portions of the conch, and (3) a group in which the retractors were attached ventrally ("ventromyarian"). Dorsomyarian annular elevations are found in the Ellesmeroceratina, in the Michelinoceratina, in secondarily straight or endogastric Lituitidae (Tarphyceratina), and in all known ammonoids, regardless of conch form (Crick, 1898). In all the nautiloid groups just enumerated, the conch plan is essentially that of an orthoceracone, endogastric cyrtoceracone, or brevicone. Dorsomyarian Michelinoceratina are thought to have evolved from the Baltoceratidae, dorsomyarian Ellesmeroceratina characterized by conchs of similar form. However, even though it has been suggested (Schindewolf, 1942) that the Lituitidae were likewise derived from straight "Orthoceracea", the bulk of structural and stratigraphic evidence (Sweet, 1958) indicates otherwise and the family is now thought to be closely related to the Trocholitidae (Tarphyceratina), which apparently have a ventromyarian annular elevation. Hence, it seems probable that the dorsomyarian elevation of the lituitids is, like the development of heavy cameral deposits in the same group, an "acquired" character, to be associated, most probably, with the late assumption of a secondarily longiconic conch. It seems reasonable to suppose that if the dorsomyarian condition were mechanically satisfactory in groups with a fundamentally straight or slightly curved conch, the same plan would be similarly satisfactory in groups that attained this same form secondarily by uncoiling. In nautiloids, then, the association of dorsal retractor-attachment and longiconic conchs may be a reflection of similar adaptation, attained independently in groups only remotely related genetically. Therefore, any general use of this feature to characterize a phylogenetic sequence, or a major taxonomic unit, would be open to question.

Ammonoids were almost certainly derived from nautiloids, but the source of this group in the Nautiloidea is, as yet, a moot question. A considerable body of opinion favors *Bactrites*, or some similar form, as the ammonoid ancestor, and *Bactrites*, itself, a longiconic orthoceracone with a marginal siphuncle, has been referred, at one time or another, to both the Nautiloidea and the Ammonoidea. If *Bactrites* is considered to be the ammonoid ancestor, whether or not it is an ammonoid or nautiloid, it seems con-

sistent to predict that it, like known Michelinoceratina, was dorsomyarian. Furthermore, it may be that ammonoids attained stability with respect to muscle-attachment, as they seem to have done with respect to siphuncular structure, early in their history. This could explain the fact that ammonoids seem invariably to be dorsomyarian, regardless of the adaptational plasticity suggested by the conchs of late Mesozoic representatives of the order. If, on the other hand, ammonoids descended from early Paleozoic coiled nautiloids, like *Barrandeoceras*, as Spath (1933) suggests, the adaptive or mechanical significance of the dorsomyarian condition disappears. That is, the early Paleozoic coiled nautiloids appear to have been ventromyarian and rather closely related in other ways.

Known pleuromyarian nautiloids are coiled, generally involute forms, similar to *Nautilus;* furthermore, they all belong in families known, or thought to be rather closely related on the basis of other features and derived, fundamentally, from a common radical in the ventromyarian Oncoceratina. This suggests, as does the gross similarity in conch plan, that pleuromyarian nautiloids were adapted to virtually the same mode of life. Consequently, the lateral position of the retractor-muscle attachment impressions is of taxonomic significance. However, it appears to define only a very large group, within which detailed relationships must still be determined from a combination of other features.

The ventromyarian annular elevation is apparently characteristic of early Paleozoic coiled nautiloids belonging in the suborders Tarphyceratina and Barrandeoceratina, but it is also present in several families of the Oncoceratina, in one of the three families of Ascoceratina, and in at least one endogastric family of the Discosorina. The Tarphyceratina and Oncoceratina are thought (Flower, 1954, etc.) to be closely related and it is probable that they represent two of the adaptively and structurally specialized derivatives of a common ancestral group (the Ellesmeroceratidae) in the Ellesmeroceratina. The Barrandeoceratina are closely related to the Tarphyceratina and probably developed from that group. The Discosorina, on the other hand, are primitively endogastric forms, thought (Flower & Teichert, 1957) to represent a stock derived independently from early Ordovician Plectronoceratidae, the group that almost certainly gave rise to the Ellesmeroceratidae, as well. One might then, regard the ventromyarian condition of *Parryoceras euchari* as the condition prevalent in the Discosorina and might expect to find that, in exogastric Discosorina, the retractors were also attached ventrally, as they are in the Oncoceratina. This implies that the group, or groups, of early Ordovician Ellesmeroceratina ancestral to the Tarphyceratina, Barrandeoceratina, and Oncoceratina on the one hand, and the Discosorina on the other, were probably similar in being ventromyarian and that the Baltoceratidae, from which the majority of dorsomyarian forms seems to have been derived, represent a group of Ellesmeroceratina specialized not only with respect to conch form and siphuncular structure, but also with respect to the arrangement of the elements of the muscle systems.

The Ascoceratidae, which seem also to be ventromyarian, are generally thought (Flower, 1941, 1954) to have developed from the Michelinoceratina, a group apparently characterized by dorsally situated retractor-attachment impressions. Late in their development, however, ascoceratids cast off the early longiconic portions of the conch and became inflated, somewhat exogastric brevicones; hence, it may be that this group is, at least in part, homeomorphic with other ventromyarian nautiloids with regard to the location of principal elements of the annular elevation.

Jackson (1890) pointed out long ago that, in pelecypods, the monomyarian condition of the adductors is attained independently in several only distantly related groups, apparently in connection with adaptive shifts in the relative positions of the hinge and body axes. Swinnerton (1947) describes graphically the attainment of a monomyarian condition in certain types of pelecypod adaptation, the implication being that a similar condition would be found in most pelecypods, regardless of their ancestry, adapted to the conditions he outlines. The conclusions of Jackson and Swinnerton with regard to pelecypods cannot, of course, be applied directly to cephalopods, but it seems

probable that, in at least certain cases, the attainment of dorsomyarian or ventromyarian musculature in nautiloids, like the development of monomyarian musculature in pelecypods, represents not relationship but adaptive convergence. Consequently, in nautiloids, as in pelecypods, it seems best, at least for the present, to accord muscle-attachment patterns a secondary taxonomic role. In connection with other features of the cephalopod shell, however, muscle-attachment patterns may be expected to provide information concerning the mode of life, adaptations, and specializations of fossil cephalopods—areas of cephalopod paleobiology about which we know very little.

REFERENCES

APPELLÖF, A., 1893, Die Schalen von *Sepia*, *Spirula*, und *Nautilus:* K. Svenska Vetensk. Akad., Handl., bd. 25, no. 7, p. 1–106, pls. 1–12.

ARKELL, W. J., FURNISH, W. M., KUMMEL, BERNHARD, MILLER, A. K., MOORE, R. C., SCHINDENWOLF, O. H., SYLVESTER-BRADLEY, P. C., & WRIGHT, C. W., 1957, Cephalopoda, Ammonoidea: Treatise on Invertebrate Paleontology, R. C. Moore, editor, Part L, Mollusca 4, i–xxii, 490 p., Lawrence, Kansas. Univ. Kansas Press and Geol. Soc. America.

BARRANDE, JOACHIM, 1866–1877, Système Silurien du centre de la Bohême: Pt. 1, v. 2, Cèphalopodes. Prague, pls. 108–244 published in 1866: Texte 1 in 1867; pls. 351–460 in 1870; Texte 2 in 1870; Texte 3 in 1874; Texte 5 in 1877.

CRICK, G. C., 1898a, On the muscular attachment of the animal to its shell in some fossil Cephalopoda (Ammonoidea): Linnean Soc. London, Trans., s. 2, v. 7, p. 71–113, pls. 17–20.

——, 1898b, Descriptions of new or imperfectly known species of *Nautilus* from the Inferior Oolite, preserved in the British Museum (Nat. Hist.): Malacolog. Soc. London, Proc., v. 3, pt. 3, p. 117–139.

DEWITZ, H., 1879a, Die Wohnkammer regulärer Orthoceratiten. Gesell. naturf. Freunde Berlin, Sitzungsber., 1879, no. 3, p. 27–38.

——, 1879b, Der Verwachsungsband der Vaginaten. Gesell. naturf. Freunde Berlin, Sitzungsber., 1879 no. 9, p. 133–147.

——, 1880, Beiträge zur Kenntnis der in den Ostpreussischen Silurgeschieben vorkommenden Cephalopoden: Phys.-ökon. Gesell. Königsberg, Schr., Bd. 20, p. 162–180, pl. 4.

FLOWER, R. H., 1941, Development of the Mixochoanites: Jour. Paleontology, v. 15, p. 523–548, pls. 76–77.

——, 1946, Ordovician cephalopods of the Cincinnati region: Bull. Am. Paleontology, v. 29, no. 116, p. 1–656, pls. 1–50.

——, 1954, Cambrian cephalopods: New Mexico Bur. Mines, Bull. 40, p. 1–48, pls. 1–3.

——, & KUMMEL, BERNHARD, 1950, A classification of the Nautiloidea: Jour. Paleontology, v. 24, p. 604–616.

——, & TEICHERT, CURT, 1957, The cephalopod order Discosorida: Univ. Kansas, Paleont. Contrib., Mollusca, art. 6, p. 1–144, pls. 1–43.

FOERSTE, A. F., 1930. Three studies of cephalopods: Denison Univ. Bull., Jour. Sci. Labs., v. 29, no. 10, p. 265–381, pls. 41–63.

——, 1936, Silurian cephalopods of the Port Daniel area on Gaspé Peninsula, in eastern Canada: Denison Univ. Bull., Jour. Sci. Labs., v. 31, p. 21–92, pls. 4–26.

FOORD, A. H., 1900, Monograph on the Carboniferous Cephalopoda of Ireland, part 3: Palaeont. Soc. Mon., p. 49–126, pls. 18–32.

——, & CRICK, G. C., 1889, On the muscular impressions of *Coelonautilus cariniferus*, J. deC. Sowerby, sp., compared with those of the recent *Nautilus:* Geol. Mag., Dec. 3, v. 6, p. 494–498.

——, & ——, 1890, On the muscular impressions of some species of Carboniferous and Jurassic nautiloids compared with those of the recent Nautilus: Annals and Mag. Nat. History, s. 6, v. 5, p. 220–224.

GRIFFIN, L. E., 1900, The anatomy of *Nautilus pompilius:* Nat. Acad. Sci., Mem., v. 8, mem. 5, p. 101–230, pls. 1–17.

JACKSON, R. T., 1890, Phylogeny of the Pelecypoda. The Aviculidae and their allies: Boston Soc. Nat. Hist., Mem., v. 4, no. 8, p. 277–400, pls. 23–30.

KUMMEL, BERNHARD, 1953, American Triassic coiled nautiloids: U. S. Geol. Survey, Prof. Paper 250, p. 1–95, pls. 1–19.

LOESCH, K. C., 1914, Die Nautilen des weissen Jura: Erster Teil: Palaeontographica, Bd. 61, p. 57–146, pls. 10–15.

MOJSISOVICS, E. M., 1873, Das Gebirge um Hallstatt. 1. Die Cephalopoden der hallstatter Kalke: K.-K. geol. Reichsanst., Abh., Bd. 6, Hft. 1, p. 1–82, pls. 1–32.

——, 1882, Die Cephalopoden der mediterranean Triasprovinz: K.-K. geol. Reichsanst., Abh., Bd. 10, p. 1–322, pls. 1–94.

MILLER, A. K., 1947, Tertiary nautiloids of the Americas: Geol. Soc. America, Mem. 23, p. 1–234, pls. 1–100.

——, 1951, Tertiary nautiloids of west-coastal Africa: Mus. Congo Belge, Ann., ser. 8, sci. geol., v. 8, p. 1–88, pls. 1–31.

——, DUNBAR, C. O., & CONDRA, E. C., 1933, The nautiloid cephalopods of the Pennsylvanian system in the Mid-continent region: Nebraska Geol. Surv., s. 2, Bull. 9, p. 1–240, pls. 1–24.

MUGGLIN, FRANZ, 1939, Beiträge zur Kenntnis der Anatomie von *Nautilus macromphalus* G. B. Sow.: Naturf. Gesell. Zürich, Vjschr., Jahrg. 84, no. 1–2, p. 25–118.

MUTVEI, HARRY, 1957, On the relations of the principal muscles to the shell in *Nautilus* and some fossil nautiloids: K. Svenska Vetensk. Akad., Arkiv. för Min. och Geol., bd. 2, no. 10, p. 219–254, pls. 1–20.

NOETLING, FRITZ, 1882, Ueber *Lituites lituus*

Montfort: Deutsche geol. Gesell., Zeitschr., Bd. 34, p. 156–192, pls. 1–11.

OWEN, RICHARD, 1832, Memoir on the pearly Nautilus (*Nautilus pompilius* Linn.) with illustrations of its external form and internal structure: London, p. 1–68, pls. 1–8.

SCHINDEWOLF, O. H., 1942, Evolution im Lichte der Paläontologie. Bilder aus der Stammesentwicklung der Cephalopoden: Jenaische Zeitschr. f. Medizin u. Naturwiss., Bd. 75, p. 324–386, pl. 1.

SCHRÖDER, HENRY, 1881, Beiträge zur Kenntnis der in ost- und westpreussischen Diluvialgeschieben gefunden Silurcephalopoden: Phys.-ökon. Gesell. Königsberg, Schr., Bd. 22, p. 54–96, pls. 2–4.

SPATH, L. F., 1933, The evolution of the Cephalopoda: Biol. Rev., v. 8, p. 418–462.

STENZEL, H. B., 1952, Living *Nautilus:* Treatise on Invertebrate Paleontology, R. C. Moore, editor, preprint of Part H, Cephalopoda, Nautiloidea, p. 2–19.

SWEET, W. C., 1958, The Middle Ordovician of the Oslo region, Norway. 10. Nautiloid cephalopods: Norsk Geol. Tidsskr., bd. 38, hft. 1, p. 1–178, pls. 1–21.

——, & MILLER, A. K., 1957, Ordovician cephalopods from Cornwallis and Little Cornwallis islands, District of Franklin, Northwest Territories: Geol. Surv. Canada, Bull. 38, p. 1–86, pls. 1–8.

SWINNERTON, H. H., 1947, Outlines of Palaeontology, 3d ed.: London, Edward Arnold & Co., 393 p.

WAAGEN, WILLIAM, 1870, Über die Ansatzstelle der Haftmuskeln beim *Nautilus* und den Ammoniden: Palaeontographica, Bd. 17, no. 5, p. 185–210, pls. 39–40.

WILLEY, ARTHUR, 1902, Contribution to the natural history of the pearly *Nautilus:* A. Willey's Zool. Res. pt. 6, p. 736–830, pls. 75–83. Cambridge Univ. Press.

EXPLANATION OF PLATE 43

FIGS. *1–4*—*Metacoceras* sp. Left lateral, dorsal, ventral, and right lateral views, ×1.5, of a fragmentary internal mold of part of the outer volution. Kendrick shale (Middle Pennsylvanian), near junction of Brushy fork and Home branch of Buffalo Creek, Pike County, Kentucky (NW¼ central rectangle, Harold, Kentucky quadrangle). Ohio State Univ. Geol. Mus. No. 19367.

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2

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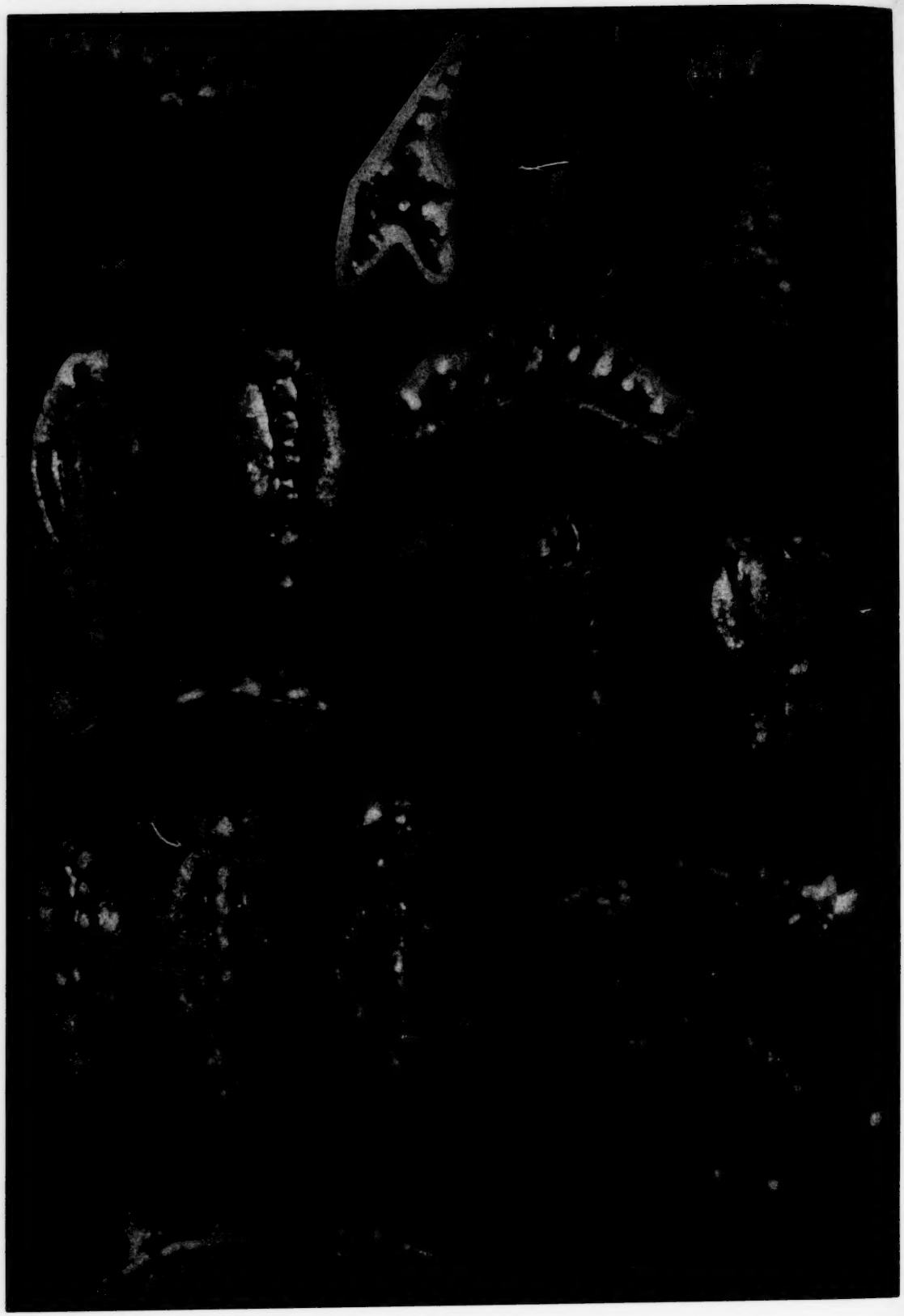
4



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CONODONTS FROM THE TRIASSIC OF NEVADA AND UTAH

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ABSTRACT—Triassic conodonts have been found in limestone sections from the Wasatch Mountains of north-central Utah to ranges in east-central Nevada. Although the largest concentrations of conodonts are in the *Meekoceras* ammonoid zone, certain species range several hundred feet above and below this time marker. Two new genera, *Parachirognathus* and *Furnishius*, and new species of *Gondolella*, *Prioniodina*, and *Hindeodella* are described.

IN 1956 Müller described a Lower Triassic conodont fauna, the first known from North America. The knowledge of Triassic conodonts until 1956 was reviewed (Branson & Mehl, 1941; Eicher, 1946, 1947; Youngquist, 1952). Since then investigations of Triassic conodonts have continued in this country (Clark, 1957). In Europe Huckriede 1955, 1958), Diebel (1956), and Tatge (1956) have recorded Triassic forms. Only the papers by Tatge (1956) and Huckriede (1958) are concerned with description of a fauna.

Müller (1956a) has reported another Triassic fauna, as yet undescribed, from the Middle Triassic Pit Shale in western Nevada (p. 820). This is the only other reported Triassic conodont fauna in North America. Knowledge of Triassic conodonts is limited because there are few marine Triassic rocks. Further investigation of the thick sequence of western Nevada Triassic may yield additional information which may be used in zonation and correlation of Triassic rocks throughout the world.

During the summers of 1955 and 1956 several thousand pounds of Triassic rock were collected from the western Utah and eastern Nevada area and checked for microfossils. Conodonts were found to be present in several thousand feet of Triassic limestone at localities from the Wasatch Mountains, east of Salt Lake City, to east-central Nevada (Text-fig. 1). In some instances, the conodonts aided in identifying the age of rocks of uncertain stratigraphic position (Clark, 1957), yet they are not abundant in the Great Basin Triassic. The only concentrations encountered have been in the *Meekoceras* ammonoid zone and they are not always abundant nor well preserved even in this interval. Above and below this zone only a few conodonts have been found but their usefulness in stratigraphic work warrants this report.

Müller's fauna (1956a) was from the

EXPLANATION OF PLATE 44

All figures are unretouched photographs, ×88, except *7*, which is ×26. All but *1–6*, from Dinner Springs Canyon, north of Montello, Nevada.

FIGS. *1–6—Furnishius triserratus* Clark, n. gen., n. sp. *1,2,6*, Paratype, upper, lower, and inner lateral views, SUI 10182; *3,4*, holotype, upper and lower views, SUI 10183; and *5*, upper view of broken specimen showing inner flange and convergence of three bars. From Lower Triassic *Meekoceras* beds at Gulf Oil Company, Dolly Varden No. 1, a few miles north of Currie, Nevada.

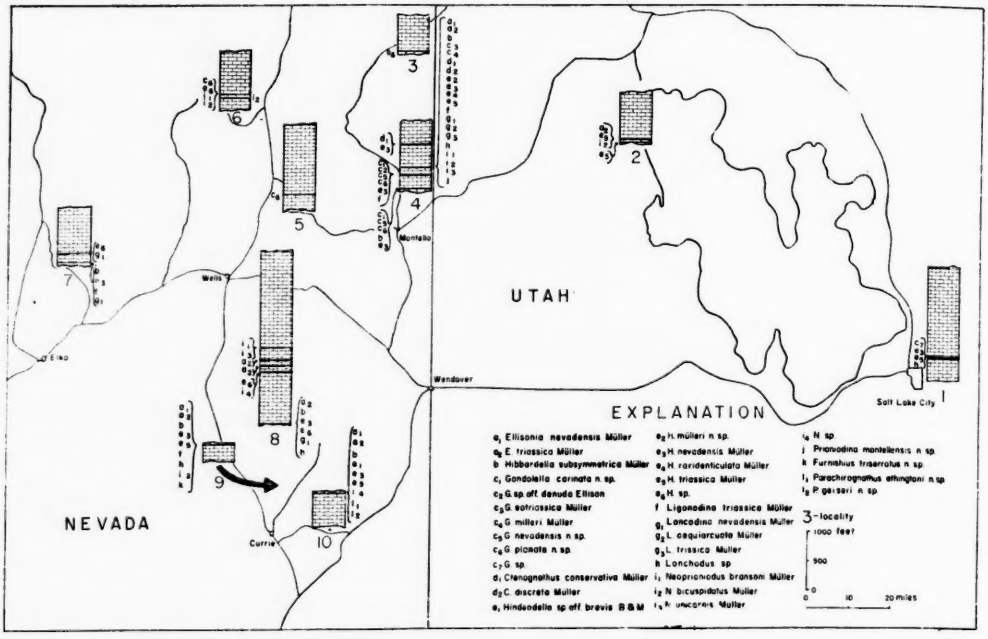
7—Prioniodina montellensis Clark, n. sp., holotype. From *Meekoceras* beds. SUI 10177.

8–10—Gondolella planata Clark, n. sp., holotype. Lower, upper, and lateral views, SUI 10175. From 39 feet above base of Lower Triassic.

11–14—Gondolella nevadensis Clark, n. sp. *11*, Paratype, lower view. SUI 10171; *12–14*, holotype, upper, lower, and lateral views. From 30 feet above base of Lower Triassic. SUI 10172.

15–19—Gondolella carinata Clark, n. sp. *15,18*, Paratype, upper and lateral views, SUI 10173, from 290 feet above base of Lower Triassic; and *16,17,19*, holotype, upper, lower, and lateral views, from 30 feet above base of Lower Triassic. SUI 10174.

20—Gondolella sp. aff. *G. denuda* Ellison. From 220 feet above base of Lower Triassic, SUI 10176.



TEXT-FIG. 1—Stratigraphic and geographic distribution of Triassic conodonts in Nevada and Utah.

Loc. 1 Between Dry Canyon and Red Butte Canyon, Utah, sec. 34, T. 1 N., R. 1 E.
Loc. 2 Hogup Mountains, Utah, T. 8 N., R. 11–12 E.
Loc. 3 Trout Creek, Nevada, T. 47 N., R. 69 E.
Loc. 4 Dinner Springs Canyon, Nevada, T. 42 N., R. 69 E.
Loc. 5 Wilkins Ranch, Nevada, T. 40 N., R. 64–65 E.
Loc. 6 O'Neil Pass, Nevada, T. 44 N., R. 61 E.
Loc. 7 Coal Canyon, Nevada, T. 38 N., R. 56 E.
Loc. 8 Spruce Mountain, Nevada, T. 30 N., R. 64 E.
Loc. 9 Dolly Varden No. 1 Well Site, Nevada, T. 28 N., R. 65 E.
Loc. 10 Currie, Nevada, T. 28 N., R. 65 E.

Meekoceras limestones of Locality 4 of this report (Text-fig. 1) and was taken from a small sample (p. 820) which yielded a remarkably complete fauna. Additional work on hundreds of pounds of material from 24 localities in the western Utah-eastern Nevada area has revealed only a few different forms. The stratigraphic and geographic distribution of the fauna first described by Müller (1956a) and those forms described as new herein are the subject of this paper. Nomenclature and terminology of many authors, including Müller (1956b), is followed.

Most of the work connected with preparation of samples was done at the State University of Iowa and the writer acknowledges the helpful advice of W. M. Furnish, K. J. Müller, and A. K. Miller. Preparation of manuscript and photography was done at Southern Methodist University. The collections are deposited at the State University of Iowa.

CONODONT BEARING ROCK

The *Meekoceras* limestones of middle Lower Triassic age have yielded the best preserved and most abundant faunas in the Great Basin Triassic. Müller's fauna (1956a) was from a coarse-grained limestone of the *Meekoceras* zone north of Montello, Nevada (Loc. 4, Text-fig. 1). The *Meekoceras* beds at this locality are 30 feet thick and consist of two limestone beds separated by 10 feet of calcareous shale. The conodonts are associated with the cephalopods which are abundant in the limestones. Conodonts, unbroken and well preserved, were removed from living chambers of the cephalopods as well as from the limestone matrix. Conodonts were not found in the non-cephalopod bearing part of the limestone. The *Meeko-*

ceras zone at the other localities (Text-fig. 1) is much thinner and contains only a few cephalopods in a dense limestone matrix. Conodonts are not so plentiful in these areas.

The conodonts from above and below the *Meekoceras* beds are found in medium-to-coarse-grained limestones which contain other fossil remains. Only a few of the shales in the eastern Great Basin Triassic contain conodonts. Above the *Meekoceras* beds at locality 4 (Text-fig. 1), a thick black shale contains fish remains but only a few broken conodonts were secured. Fine-grained limestones at localities 3 & 6 (Text-fig. 1) contain few conodonts and no other fossils. At locality 8 (Text-fig. 1), conodonts were found in association with hundreds of microscopic gastropods and echinoid fragments. Mature gastropods and echinoids were not found in any part of the section at this same locality.

Lithologic description of other conodont bearing beds and location of sections has been published (Clark & Stokes, 1956).

FAUNAL DISTRIBUTION

Because of the usefulness of conodonts in identifying the age of rock which may lack other guide or index fossils it is important to record the known distribution of forms, especially those which have been little studied and are relatively unknown.

The following species have not been found outside of the *Meekoceras* zone in Nevada and Utah:

Gondolella milleri Müller
G. eotriassica Müller
Ctenognathus discreta Müller
Hindeodella raridenticulata Müller
Lonchodina nevadensis Müller
Lonchodina aequiaracata Müller
L. triassica Müller
Ellisonia nevadensis Müller
Prioniodina montellensis, n. sp.
Hindeodella mülleri, n. sp.
Parachirognathus ethingtoni, n. sp.
P. geiseri, n. sp.
Furnishius triserratus, n. sp.

Of the species listed, only a very few have a wide geographic distribution in the *Meekoceras* zone. Important of those which are widespread is *Ellisonia nevadensis* Müller which has been found in the *Meekoceras* beds of localities 4, 9, & 10, and *Lonchodina nevadensis* Müller which has been found in these same beds at localities 4, 7, & 8 (Text-fig. 1).

More than a dozen species have been found to range more extensively in the Triassic. Those found in the *Meekoceras* beds and below include:

Neoprioniodus bicuspidatus Müller, found from 40 feet above the Permian to *Meekoceras* zone,
Hindeodella triassica Müller, from 10 feet above Permian to *Meekoceras* zone,
Ligonodina triassica Müller, from 210 feet above Permian to *Meekoceras* zone,
Hibbardella subsymmetrica Müller, from 38 feet above Permian to *Meekoceras* zone,
Gondolella planata, n. sp., from 30 feet above Permian to *Meekoceras* zone,
G. nevadensis, n. sp., & *G. carinata*, n. sp., from 30 feet above Permian to 120 feet below *Meekoceras* zone.

Species found in *Meekoceras* beds and above include:

Neoprioniodus unicornis Müller, from *Meekoceras* zone to 1300 feet above.

This species is present in the *Meekoceras* zone associated with

N. bicuspidatus, a species found below the *Meekoceras* beds but not above.
N. bransoni Müller, found from *Meekoceras* zone to 1300 feet above.
Ctenognathus conservativa Müller, from *Meekoceras* zone to 400 feet above.

Species found befow and above the *Meekoceras* beds include:

Ellisonia triassica Müller, one of the most common forms found is known to range from 40 feet above the Permian to 1080 feet above the *Meekoceras* zone.
Hindeodella nevadensis Müller, from 38 feet above the Permian to 400 feet above the *Meekoceras* zone.

The stratigraphic and geographic distribution is summarized as Text-figure 1.

SYSTEMATIC PALEONTOLOGY

Genus GONDOLELLA Stauffer & Plummer, 1932

Type species: *G. elegantula* Stauffer & Plummer

A *Gondolella* from Triassic rocks was recognized in 1941 by Branson & Mehl but was supposed by them to be a reworked specimen (p. 194). Müller first described a definite *Gondolella* (1956a) from Nevada, and Tatge (1956) described several species from the Middle Triassic of Germany. None of the Triassic species that has been described is closely similar to the species described here as new.

The possibility that species of *Gondolella* may prove to be useful as index fossils in

the same way as do species of *Palmatolepis* in the Upper Devonian has been suggested by Müller (1956a). Short vertical ranges are characteristic of the Triassic species but with one exception they have been found only at a single locality.

Occurrence.—Pennsylvanian to Middle Triassic.

Orientation.—The pointed narrow part is regarded as anterior, the wider part with loop on the lower surface is posterior.

GONDOLELLA NEVADENSIS Clark, n. sp.
Pl. 44, figs. 11–14

Asymmetrical unit, lanceolate, oral (upper) surface of platform narrows anteriorly and ends slightly to the rear of the anterior end of the carina. Greatest width of platform is just posterior the center of unit. Posterior part of platform has abruptly curved margin which meets carina without gradual tapering as in anterior portion. Platform is smooth and is bowed upward. Carina separated from platform on both sides by shallow grooves, is low and composed of 11 to 13 nodes or denticles, the largest of which are on the anterior and posterior parts and inclined posteriorly. Largest denticle is the posterior one although on some individuals a posterior pair of equally large size is present. Each denticle is discrete and in the anterior portion of the carina very widely separated. Anterior part of carina ends at or is slightly longer than the platform but the posterior part of the carina extends out two denticles distance beyond the posterior margin of the platform. This is expressed on the lower or aboral surface by a large keeled knob which bears the small loop. Furrow wide only in loop area and becomes narrow for the length of the individual and forms a keel anteriorly which is only slightly grooved.

Discussion.—Of the several species encountered in the Lower Triassic rocks, *Gondolella nevadensis*, n. sp., is by far the most abundant. It can be distinguished from Pennsylvanian species by the unsculptured platform, shape and bowing of platform, posterior extension of carina beyond platform and possession of loop-bearing knob. It can be distinguished from the smooth platformed Permian species as follows: from *G. phosphoriansis* Youngquist, Hawley & Miller (1951), by possession of discretely denticulate carina for entire length and posterior extension of carina with loop-bearing knob; from *G. idahoensis* Youngquist, Hawley & Miller, by these same features and in addition by the anteriorly tapering platform. The Triassic species of Müller (1956a) from the *Meekoceras* zone have a very high carina and a sculptured-ridged platform whereas the Middle Triassic species of Tatge (1956) though similar in the smooth platform and general shape, lack the carina extension. *G. nevadensis* is most similar to *G. haslachensis* Tatge from the Middle Triassic and is suggestive of an ancestrial form.

Occurrence.—Holotype from 30 feet above Permian, others from 30 to 270 feet above the Permian (135 feet below *Meekoceras* zone), Dinner Springs Canyon, about 18 miles north of Montello, Nevada, T. 42 N., R. 69 E., (Loc. 4, Text-fig. 1).

Repository.—S.U.I. 10171, 10172.

GONDOLELLA CARINATA Clark, n. sp.
Pl. 44, figs. 15–19

Asymmetrical unit with rather narrow platform for entire length. Platform tapers anteriorly and does not extend for length of carina as anterior portion of carina extends two to three denticles distance beyond farthest extension of platform. Greatest width of platform is at center from which it tapers posteriorly and curves inward between last two denticles of carina and then flares outward as a small secondary platform which completely surrounds the last denticle of the carina as a brim. This brim-like portion of the platform is distinct and is an extension beyond the posterior-most part of the carina. Platform is bowed upward, lateral portions are slightly flexed and separated from carina by shallow grooves. Platform is smooth. Carina is low, highest denticles on anterior and posterior positions and only slightly inclined posteriorly, between 9 and 15 in number. Lower or aboral surface has narrow furrow which has its greatest width under the secondary or brim-like portion of the platform where it forms the loop. Loop narrows anteriorly and becomes a ridge which merges with the carina to form a distinct keel which extends beyond the anterior-most part of the platform (Pl. 44, fig. 19).

Discussion.—This species can be distinguished from all other species of *Gondolella* by the anterior extension of the carina which merges with the ridge on the lower surface and extends beyond the anterior-most part

of the platform, and by the possession of a small brim-like platform which surrounds the last denticle at the posterior end. Younger individuals of this species (from 200 feet higher than the holotype) show some variation in the brim-like platform. It extends beyond posterior part of carina but is not so restricted or deeply curved inward between the last two denticles. The anterior carina-keel combination is pronounced in all individuals of this species.

Gondolella mombergensis Tatge from the Middle Triassic of Germany is somewhat similar to *G. carinata*, n. sp., in general size and in the anterior extension of the carina, but it lacks the posterior brim-like platfrom, which is distinctive on all specimens of this species.

Occurrence.—Holotype from 30 feet above base of Triassic and other individuals of this species from 30 to 290 feet above the base, the highest occurrence 115 feet below the Lower Triassic *Meekoceras* zone, Dinner Springs Canyon, 18 miles north of Montello, Nevada, T. 42 N., R. 69 E. (Loc. 4, Text-fig. 1).

Repository.—S.U.I., 10173, 10174.

GONDOLELLA PLANATA Clark, n. sp.
Pl. 44, figs. 8–10

Asymmetrical unit, lanceolate, oral surface of platform smooth with wide flat lateral extensions. Groove separates carina from platform and is wider and deeper anteriorly and posteriorly than in the middle. Platform narrows anteriorly and is same length as carina. Greatest width is slightly posterior of center of unit; posterior portion of platform coverges and meets posterior part of carina. Whole unit only slightly arched or bowed upward and is expressed by the keel as the carina is almost straight. Carina low with 8 to 10 denticles or nodes which are widely spaced and somewhat larger than the nodes of the carina of other Triassic species. Anterior and posterior nodes are larger. Wide furrow on lower or aboral surface, loop does not extend to posterior portion of platform. Keel formed anteriorly and extends to anterior margin.

Discussion.—This species is rather flat and broad as compared to *Gondolella nevadensis*, n. sp., and *G. carinata*, n. sp., and is distinguished from these species by the shape of the platform, the fewer number and larger size nodes, the very slight arching, and especially by the fact that the carina and the platform extend the same distance anteriorly and posteriorly. It differs from the Paleozoic species by these same characteristics.

Occurrence.—*Gondolella planata*, n. sp., has the greatest geographic and stratigraphic range of the known Triassic species. It is found from 30 feet above the base of the Lower Triassic to 420 feet above in the *Meekoceras* zone. The holotype is from 39 feet above the base of the Lower Triassic in Dinner Springs Canyon, 18 miles north of Montello, Nevada, T. 42 N., R. 69 E. Other individuals of this species have been found in the *Meekoceras* beds of Wilkins Ranch (Loc. 5, Text-fig. 1), O'Neil Pass (Loc. 6, Text-fig. 1), and the Wasatch near Salt Lake City (Loc. 1, Text-fig. 1).

Repository.—S.U.I. 10175.

GONDOLELLA sp. aff. G. DENUDA Ellison
Pl. 44, fig. 20

A single specimen was found which is similar to *Gondolella denuda* Ellison. It lacks a wide platform and only 3 of the denticles including the large posterior denticle are present but their relationship to the platform certainly suggests *G. denuda*. Ellison (1941) described *G. denuda:*

> Blade-like, consisting of 15 or more subequal denticles discrete for over three-fourths their length; posterior denticle larger than other denticles, pointed, sharp-edged, conical and discrete.

Occurrence.—220 feet above the base of Lower Triassic in Dinner Springs Canyon, 18 miles north of Montello, Nevada, T. 42 N., R. 69 E. This occurrence is about 200 feet below the *Meekoceras* zone.

Repository.—S.U.I., 10176.

PRIONIODINA MONTELLENSIS Clark, n. sp.
Pl. 44, fig. 7

Slightly arched blade with large cusp located three-fifths the distance between anterior and posterior end. Anterior portion has 8 circular denticles, sharply pointed, largest toward center of conodont. Base of individual denticles rise from base of blade at anterior end to a position near the midpoint where the blade is as thick as the denticle is long. Denticles at right angles to blade on anterior portion, inclined posteriorly from about center of conodont to posterior end. Denticles are separated at base by a distance about half the thickness of individual denticles. Central cusp is one and

a half times as large at base and one and a half times taller than other denticles. Posterior part of unit consists of four denticles which are larger than those anteriorly placed. Beneath cusp is a narrow only slightly grooved excavation which extends slightly to the posterior and anterior of the cusp. Whole blade is slightly bowed inward.

Discussion.—This species is not common in the eastern Great Basin Triassic. Only four individuals were found and those are from the *Meekoceras* beds of one locality. *Prioniodina montellensis*, n. sp., is similar to *P. curta* Huddle (1934) but is distinguished by the shape and spacing of the denticles.

Occurrence.—From the Lower Triassic *Meekoceras* beds in Dinner Springs Canyon, 18 mile north of Montello, Nevada, T. 42 N.. R. 69 E.

Holotype.—S.U.I. 10177.

HINDEODELLA MÜLLERI Clark, n. sp.
Pl. 45, figs. 1,2

Anterior portion of bar straight and comprises three-fourths of total length of unit. Posterior portion is curved inward at approximately 45 degrees and comprises remaining fourth of total length. Cusp is at 45 degree flexure and on the straight or anterior portion of bar. 9 to 10 denticles on anterior part, all slightly inclined posteriorly. Denticles are fused for about a third of total length and then are discrete. All denticles rounded and sharply pointed. Posterior part bears three to four denticles which are smaller, taper posteriorly and are more widely spaced than those denticles on the anterior or straight portion of the conodont. Lower or aboral surface is ridge-like, no escutheon.

Discussion.—This species can be distinguished from all other species of *Hindeodella* by the fact that the posterior end is flexed inward. All other species are straight or have their anterior portion flexed inward. Hass (1953, p 82) records that on *H. ensis* Hass both the posterior and anterior portion of the bar curve inward. Rexroad (1957, p. 32) describes one fragment of a specimen which "is similar to typical hindeodellids except that the denticles are inclined in the direction opposite to that expected." This specimen has alternating sized denticles and does not belong with *H. mülleri* n. sp., but is the only other specimen of *Hindeodella* known to the writer in which the normal denticle inclination and inward flexure are reversed. Except for the posterior bar being flexed inward (or reversal in direction of denticles), *H. mülleri*, n. sp., is a typical *Hindeodella*. Ellison (1941) describes a strongly flexed anterior bar on a *H.* sp. from the Pennsylvanian. The holotype is sinistral; paratypes include five sinistral and two dextral specimens.

Occurrence.—From the Lower Triassic *Meekoceras* limestones, Dinner Springs Canyon, 18 miles north of Montello, Nevada, T. 42 N., R. 69 E.

Repository.—S.U.I. 10178, 10179.

HINDEODELLA sp. aff. H. BREVIS
Branson & Mehl
Pl. 45, figs. 6,9

Hindeodella brevis BRANSON & MEHL, 1934, Missouri Univ. Studies, v. 8, p. 195, pl. 14, figs. 6,7; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 103.

Several specimens were found in a single sample which are similar to *Hindeodella brevis* Branson & Mehl. The conodonts have a greatly thickened oral bar with a large cusp rising from the sigmoidal shaped bar from a central position. The denticles on either side of the main cusp are equal in size, rounded and partially fused. The bar is slightly arched in the vertical plane and forms a "w" shaped unit when viewed from upper or lower surface. The lower surface is a sharp ridge with no escutcheon.

Occurrence.—Lower Triassic *Meekoceras* beds, about 5 miles east of Currie, Nevada (Loc. 10, Text-fig. 1), T. 28 N., R. 65 E.

Repository.—S.U.I. 10180, 10181.

Genus FURNISHIUS Clark, n. gen.
Type species: *Furnishius triserratus* Clark, n. sp.

Asymmetrical conodonts composed of three bars, two anterior and one posterior. The two anterior bars converge in an acute "v" pattern and form a single bar which is slightly curved and extends posteriorly. The resultant outline is a "y" shaped unit which is not strongly arched as in the Hibbardellidae. Denticles all rounded needle-like and discrete, only slightly directed posteriorly and all of approximately same size. No central cusp. In area of junction of anterior bars and single posterior extension there is a small flattened platform which bears nodes or denticles. There is a prominent inward directed lateral process or flange at the posterior part of the small platform which may bear denticles. This

gives the conodont four distinct axes of growth. Aboral or lower surface beneath platform area is very slightly flattened but not excavated. Lower surface of bars is keel-like for entire length.

This genus is slightly similar to *Cladognathus* Rexroad (1957) but is easily distinguished by the 45 degree "v" shaped anterior bars, presence of a small platform in area of junction of 4 axes and absence of a central cusp. These same characters distinguish it from *Ctenognathodus* Branson & Mehl and the symmetrical Hibbardellidae of Müller (1956a). The four directions of growth suggest a relationship to *Ancryodella* of the Upper Devonian.

Occurrence.—The type species and only forms assigned to this genus are from the *Meekoceras* limestones of Lower Triassic age from the site of the Gulf Oil Company, Number 1 Dolly Varden Well, T. 28 N., R. 65 E., a few miles north of Currie, Nevada.

FURNISHIUS TRISERRATUS Clark, n. sp.
Pl. 44, figs. 1–6

Unit strongly asymmetrical, posterior bar slightly curved inward and bowed upward. Posterior bar has seven denticles of equal size, discrete rounded and needle-like. Anterior bars converge acutely and form small platform with a single node located at the center. Between inner anterior bar and posterior bar extension there is an inward projecting flange which bears nodes. Anterior bars bear denticles which are in rows, denticles of one row alternating in position with those on other. Outer anterior bar has two small denticles on inner row and three slightly larger ones on outer row. All denticles inclined only slightly posteriorly.

Lower or aboral surface is broadest under junction of "y" or small platform. This area extends into a narrow ridge which runs the entire length of each bar. No escutcheon.

Occurrence.—As for genus.

Repository.—S.U.I. 10182, 10183.

Genus PARACHIROGNATHUS Clark, n. gen.
Type species: PARACHIROGNATHUS ETHINGTONI Clark, n. sp.

A hand-shaped conodont with a cupped or concave inner surface. Unit consists of a large basal blade which has on the upper surface 7 to 15 discrete needle-like to lenticular denticles of unequal size. There may be a central cusp but often there is no denticle which is larger than all others. Unit bowed inward, thin, translucent; lower or aboral surface is a sharp straight ridge showing no upward bowing. Small narrow ridge separates base of denticles from blade and this may be paralleled by several concentric bands on blade below. On type species the denticles are curved inward and inclined posteriorly but on other species of the genus the denticles are not inclined in a uniform direction and an arbitrary orientation must be made. Base of denticles extends upward from convex upper surface of blade and so even equal sized denticles reach unequal heights. Lamellar structure well shown but germ denticles not apparent.

Discussion.—Superficially this genus is quite similar to species of *Chirognathus*, a fibrous conodont. With one exception, *Chirognathus* has not been reported from other than Middle Ordovician (Fay, 1952). Sweet (1955) considers the one exception, *C. neossa* Cooper from the Lower Mississippian, not to be *Chirognathus* because "it appears to be more expanded in the basal plane than is characteristic of the genus." *Parachirognathus* from the Lower Triassic has a lamellar structure which easily separates it from the fibrous *Chirognathus*. Basic distinction between the fibrous conodonts (Neurodontiformes) and the lamellar forms (Conodontiformes) has been discussed by Rhodes & Wingard (1957). *Parachirognathus* is not closely similar to any other genus known to the writer.

PARACHIROGNATHUS ETHINGTONI Clark, n. sp.
Pl. 45, figs. 3,5,7

Dextral conodont distinct from *Parachirognathus geiseri*, n. sp., the only other species known, by the posteriorly inclined denticles of unequal size. The lower surface is a sharp ridge, almost straight across; blade is large, a third total size of specimen. Posterior and anterior denticles extend from near the aboral or lower surface upward and the distance of the base from the lower margin increases from both ends toward the center where it reaches its maximum height. The largest denticle is central on the blade and is curved posteriorly and inward. Only the taller of the needle-like denticles are curved inward. Whole unit slightly bowed inward and lower margin is not arched in the vertical plane.

Discussion.—Sinistral and dextral specimens of this species have been obtained.

Specimens are translucent and exhibit lamellar structure very clearly under high magnification.

Occurrence.—From the Lower Triassic *Meekoceras* limestones, about 5 miles east of Currie, Nevada, T. 28 N., R. 65 E.

Repository.—S.U.I., 10184, 10185.

PARACHIROGNATHUS GEISERI Clark, n. sp.
Pl. 45, figs. 4,8,10,11

Hand-shaped conodont with large basal blade with straight lower margin and 9–13 denticles extending upward at right angles to convex upper surface. Denticles discrete, elongate, needle-like, and translucent; equal size common. Orientation is arbitrary as denticles are directed at right angles to convex upper surface and there is no uniform inclination. Unit is oriented as in type species, i.e. bow of unit inward, posterior on right, anterior on left. Blade has prominent concentric bands parallel to upper surface.

Discussion.—This species can be distinguished from *Parachirognathus ethingtoni*, n.sp., by the size and orientation of the denticles. On the latter the denticles are inclined posteriorly and are of unequal size. On *P. geiseri*, n. sp., the denticles are directed at right angles to the surface and are more or less of equal size.

Occurrence.—From the Lower Triassic *Meekoceras* limestones, about 5 miles east of Currie, Nevada, T. 28 N., R. 65 E.

Repository.—S.U.I. 10186, 10187.

REFERENCES

BRANSON, E. B. & MEHL, M. G., 1933, Conodont studies no. 3: Univ. Missouri Studies, v. 8, p. 171–259, 21 pls.

——, & ——, 1941, A record of typical American conodont genera in various parts of Europe: Denison Univ. Bull., v. 40, no. 14, Jour. Sci. Lab., v. 35, art. 7, p. 189–194, pl. 7.

CLARK, D. L., 1957, Marine Triassic stratigraphy in eastern Great Basin: Am. Assoc. Petroleum Geologists, Bull., v. 41, p. 2192–2222.

——, & STOKES, W. L., 1956, Preliminary survey of Triassic rocks in eastern Great Basin: *ibid.*, v. 40, p. 1686–1692.

DIEBEL, K., 1956, Über Trias conodonten: Geologie, v. 5, p. 9–12.

EICHER, D. B., 1946, Conodonts from the Triassic of Sinai (Egypt): Am. Assoc. Petroleum Geologists, Bull., v. 30, p. 613–616.

——, 1947, Micropaleontology of the Triassic of north Sinai: Bull. Inst. Egypte, v. 28, p. 87–92.

ELLISON, S. P., 1941, Revision of the Pennsylvanian conodonts: Jour. Paleontology, v. 15, p. 107–143, pls. 20–23.

FAY, R. O., 1952, Catalogue of conodonts: Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, 206 p.

HASS, W. H., 1953, Conodonts of the Barnett formation of Texas: U. S. Geol. Survey, Prof. Paper 243-F, p. 69–94, pls. 14–16.

HUCKRIEDE, R., 1955, Conodonten in der mediterranen Trias: Austria Geol. Bund. Verhand., no. 4, p. 260–264.

——, 1958, Die Conodonten der mediterranen Trias und ihr stratigraphischer Wert: Paläont. Zeitschrift, b. 32, teil 3/4, p. 141–175, pls. 10–14.

HUDDLE, J. W., 1934, Conodonts from the New Albany shale of Indiana: Bull. Amer. Paleontology, v. 21, no. 72, p. 1–136, 12 pls.

MÜLLER, K. J., 1956a, Triassic conodonts from Nevada: Jour. Paleontology, v. 30, p. 818–830, pls. 95,96.

——, 1956b, Taxonomy, nomenclature, orientation, and stratigraphic evaluation of conodonts: Jour. Paleontology, v. 30, p. 1324–1340, pl. 145.

REXROAD, C. B., 1957, Conodonts from the Chester series in the type area of southwestern Illinois: Illinois Geol. Surv., Rept. Invest. 199, 43 p., 4 pls.

RHODES, F. H. T., & WINGARD, P. S., 1957, Chemical composition, microstructure, and affinities of the Neurodontiformes: Jour. Paleontology, v. 31, p. 448–454.

SWEET, W. C., 1955, Conodonts from the Harding formation (Middle Ordovician) of Colorado: Jour. Paleontology, v. 29, p. 226–262, pls. 27–29.

TATGE, U., 1956, Conodonten aus dem germanischen Muschelkalk: Paläont. Zeitschrift, b. 30, teil 1, p. 108–127, tafel 5,6; teil 2, p. 129–147.

YOUNGQUIST, W. L., 1952, Triassic conodonts from southeastern Idaho: Jour. Paleontology, v. 26, p. 650–655.

——, HAWLEY, R. W., & MILLER, A. K., 1951, Phosphoria conodonts from southeastern Idaho: Jour. Paleontology, v. 25, p. 356–364, pl. 54.

EXPLANATION OF PLATE 45

All figures are unretouched photographs, ×88, and all but *1* and *2* are from the Lower Triassic *Meekoceras* beds about 5 miles east of Currie, Nevada.

FIGS. *1,2*—*Hindeodella mülleri* Clark, n. sp. *1*, Paratype, dextral. SUI 10178; and *2*, holotype, sinistral, SUI 10179. From Lower Triassic *Meekoceras* beds, Dinner Springs Canyon, about 18 miles north of Montello, Nevada.

3,5,7—*Parachirognathus ethingtoni* Clark, n. gen., n. sp. *3*, Broken dextral specimen; *5*, paratype, sinistral, SUI 10184; and *7*, holotype, dextral, SUI 10185.

4,8,10,11—*Parachirognathus geiseri* Clark, n. gen., n. sp. *4,8,10*, Paratypes. SUI 10186; and *11*, holotype, SUI 10187.

6,9—*Hindeodella* sp. aff. *H. brevis* Branson & Mehl. *6*, SUI 10180; and *9*, SUI 10181.

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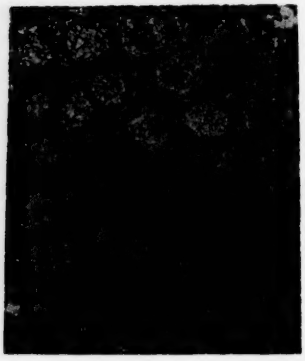

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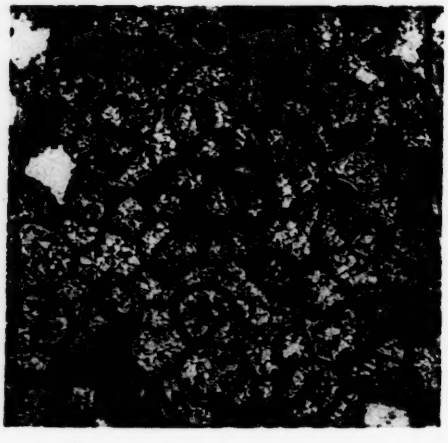

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BRYOZOANS FROM THE AMSDEN FORMATION, SOUTHWEST MONTANA

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ABSTRACT—Nine new species of bryozoans belonging to the orders Cyclostomata and Trepostomata are described from exposures of the Amsden formation in Madison and Jefferson counties, southwestern Montana. Four species are assigned to the cyclostomatous genera *Fistulipora*, *Cyclotrypa*, and *Dybowskiella*, and five species to the trepostomatous genera *Tabulipora* and *Stenophragmidium*. The range of *Stenophragmidium*, which apparently has not been hitherto recognized in North America, is extended to include its occurrence in strata of probable Pennsylvanian age.

INTRODUCTION

BRYOZOANS described herein were collected from Amsden exposures at the following localities in southwestern Montana: (1) Sappington Canyon Section (Gardner et al., 1946) near west-center of sec. 25, T. 1 N., R. 2 W., approximately 2 miles northwest of Sappington, Jefferson County, and (2) near center of sec. 19, T. 1 S., R. 3 W., approximately 2¼ miles west of the Indiana University Geologic Field Station, in Madison County.

At Locality 1 the bryozoan-bearing strata 255 feet above the top of the Madison group (Mississippian), are 4.5 feet thick. The enclosing beds form a biostrome of spiriferoid, productoid, and compositoid branchiopods; remains of gastropods, pelecypods, and crinoids are rare and fragmentary in this fauna. These strata are largely light-gray fine-grained limestone in beds that commonly range from 2 to 6 inches thick. This bryozoan-bearing zone includes irregularly lenticular shale partings up to 2 inches thick which contain hard limy nodules. Bryozoans are most abundant in the shale partings between limestone beds. These specimens were collected from beds which Sloss (1946) regarded as late Mississippian.

At Locality 2, the bryozoan-bearing beds, 321 feet above the top of the Madison group, are light gray silty limestone and highly calcareous shale that form beds less than 18 inches thick. Faunal associates mainly are spiriferoid and productoid brachiopods, large solitary tetracorals, and schizocorals. This fauna includes the brachiopod *Phricodothyris* which is a common Pennsylvanian genus. At this locality, bryozoans were obtained from weathered material surrounding a small prospect pit.

In this part of Montana the base of the

EXPLANATION OF PLATE 46

All figures ×20, except *4* which is ×60

FIGS. *1,2*—*Cyclotrypa conferta* Perry & Gutschick, n. sp. Holotype (Ind. Univ. Paleont. Coll. 5499) from the Amsden formation, Locality 2. *1*, Tangential section showing poorly developed lunaria; and *2*, longitudinal section showing plane of rejuvenation.

3–5—*Dybowskiella stipata* Perry & Gutschick, n. sp. *3*, Tangential section; *4*, tangential section showing extremities of lunaria projecting into zooecia; and *5*, longitudinal section. *3,5*, Holotype (Ind. Univ. Paleont. Coll. 5502); *4*, paratype (Ind. Univ. Paleont. Coll. 5503). Holotype and paratype are from Amsden formation, Locality 2.

6,7—*Dybowskiella regularis* Perry & Gutschick, n. sp. *6*, Tangential section; and *7*, longitudinal section. Holotype (Ind. Univ. Paleont. Coll. 5505) from the Amsden formation, Locality 2.

8,9—*Fistulipora amsdenensis* Perry & Gutschick, n. sp. *8*, Longitudinal section; and *9*, tangential section. Holotype (Ind. Univ. Paleont. Coll. 5501) from the Amsden formation, Locality 1.

Amsden formation is in sharp contact with the underlying thick or massive limestone beds in the upper part of the Mission Canyon limestone of the Madison group. The lower part of the Amsden in this area typically consists of thinly bedded (generally less than 8 inches) reddish gray and red siltstone and arenaceous shale that commonly are somewhat calcareous or dolomitic. The red colored strata give way upward to light gray thin- and thick-bedded limestone and dolomitic limestone that are commonly arenaceous. The upper contact of the Amsden with the overlying Quadrant formation of undisputed Pennsylvanian age is gradational and arbitrarily defined; commonly, beds of Amsden-like lithology are found interbedded with quartzitic rocks in the lower part of the Quadrant. For this reason the stratigraphic positions of these collections are located with respect to the Mission Canyon-Amsden contact, a stratigraphic boundary that is readily recognizable lithologically and topographically.

Until recent years, the age of the Amsden has been widely disputed since Darton (1904) named and defined the formation. As has been noted by Williams (1948), Moore *et al.* (1944), and Weller et al. (1948), geologists have assigned the Amsden to the Mississippian in some regions, to the Pennsylvanian in other areas, and commonly have maintained that the Mississippian-Pennsylvanian boundary is located within the formation. Recent papers by Henbest (1954) and Burk (1954) strongly advocate a Pennsylvanian age for the Amsden. Henbest, after commenting briefly on the foraminiferal genera from the Amsden, states:

> "No evidence of Mississippian age was recognized in these six collections. Atoka, Pennsylvanian age seemed to be rather well substantiated. Nevertheless, the foraminiferal fauna is so peculiar and the knowledge of late Mississippian and early Pennsylvanian foraminifers so incomplete that this age determination should not be accepted without reservation."

Burk (1954) concluded: " . . . faunal evidence pointed out in this paper makes it necessary to abandon the Mississippian age previously accepted for the Amsden, and confirms its Pennsylvanian age. . . . " Apparently, however, a Pennsylvanian age for the Amsden is still not unanimously accepted as McMannis (1955) reported that fossils obtained from 102 feet below the Amsden-Quadrant boundary are early Pennsylvanian, but a collection from 218 feet below this boundary contained fossils suggestive of both late Mississippian and early Pennsylvanian age.

Bryozoans here described cannot be used for regional correlation of the Amsden with equivalent rocks elsewhere in the Rocky Mountain region because of our scant knowledge of bryozoan faunas of this general age in western North America. Like many macrofossil genera, four of the five bryozoan genera (*Fistulipora*, *Cyclotrypa*, *Dybowskiella*, and *Tabulipora*) in this fauna are represented in both Mississippian and Pennsylvanian strata. *Stenophragmidium*, to the best of our knowledge, has not been recognized from this continent and, consequently, the range of this genus, at least in North America, is not known. The absence of *Archimedes* and the scarcity of *Fenestella* and *Fenestrellina* in this fauna, however, tends to indicate a Pennsylvanian age as these genera are more commonly found in Mississippian strata. Further, the underlying limestone of the Madison group commonly contains abundant fenestellid bryozoans in this area.

Distribution of bryozoan species described herein are:

Locality 1	Locality 2
Fistulipora amsdenensis (1)	*Cyclotrypa conferta* (2)
Stenophragmidium megistum (13)	*Dybowskiella stipata* (7)
	D. regularis (1)
	Tabulipora amsdenensis (32)
	T. pachymuralis (13)
	T. maculata (2)
	Stenophragmidium obscurum (1)
	S. megistum (1)

In the above tabulation, the figure in parentheses after each species indicates the number of specimens collected.

Thin sections were prepared by Wm. T. Straw, an undergraduate student in the Department of Geology at Indiana University, and were photographed by George Ringer of the Indiana Geological Survey.

SYSTEMATIC DESCRIPTIONS

Order CYCLOSTOMATA
Family FISTULIPORIDAE Ulrich, 1882
Genus CYCLOTRYPA Ulrich, 1896
CYCLOTRYPA CONFERTA Perry & Gutschick, n. sp.
Pl. 46, figs. 1,2

Zoarium encrusting, approximately 3.5 mm. thick in type specimen and composed of two growth layers separated by a distinct plane of rejuvenation. Monticules low, small, irregularly spaced (?), and lacking zooecia.

In tangential section, zooecia round to broadly ovate, closely spaced; five entire zooecia and portion of sixth almost invariably occupy a 2 mm. distance; maximum zooecial diameter (based on 20 measurements) ranges from 0.32 to 0.39 mm., averaging 0.35 mm.; interzooecial space (based on 18 measurements) ranges from 0.01 to 0.10 mm., averaging 0.06 mm.; adjacent zooecia commonly in local contact; where not in contact, adjacent zooecia separated by one, less commonly two, small subangular vesicles. Lunaria lacking on most zooecia, very obscurely developed on other apertures. Two small areas, each somewhat less than 0.6 mm. in diameter and about 3.0 mm. apart, composed solely of small subangular vesicles represent monticules.

In longitudinal section, zooecia inclined near base of zoarium and immediately above plane of rejuvenation, later erect. Diaphragms thin, horizontal, not more than three per zooecium, and lacking in many zooecia. Vesicles small, crescentic to crudely rectangular, convex outward, forming a single column or two or more interlocking columns between adjacent zooecia.

Remarks.—The characteristic features of this species are: (1) the closely spaced zooecia that are commonly in contact, and (2) the small size of the vesicles. The lunarium is lacking in the majority of zooecia and, where developed, this obsolescent structure is not sufficiently prominent in our opinion to include this species in *Fistulipora*. Structurally, *Cyclotypra conferta* is unlike any described fistuliporoid of late Mississippian or early Pennsylvanian age.

The specific name alludes to the close spacing of the zooecia.

Occurrence:—Amsden formation, Locality 2.

Repository:—Indiana University Paleontologic Collections; holotype 5499, paratype 5500

Genus FISTULIPORA McCoy, 1850
FISTULIPORA AMSDENENSIS Perry & Gutschick, n. sp
Pl. 46, figs. 8,9

Zoarium ramose, solid, the fragment 23 mm. long and 14 mm. in diameter; neither monticules nor maculae observed.

In tangential section, zooecia thin walled, typically ovate or pyriform, very rarely circular, and irregularly spaced; most commonly three entire zooecia and a portion of a fourth in 2 mm.; rarely three or four entire zooecia in a 2 mm. distance; maximum zooecial diameter (based on 10 measurements and including lunarium) ranges from 0.31 to 0.43 mm., averaging 0.38 mm.; interzooecial distance (based on 11 measurements) ranges from 0.11 to 0.30 mm., averaging 0.20 mm. Lunarium elongate, nonthickened, generally difficult to differentiate from remainder of zooecial wall, not indenting zooecial cavity, usually forming one-quarter to nearly one-half of zooecial periphery, and inconspicuous in a few zooecia. Vesicles irregularly angular, showing considerable variation in shape, and ranging from about one-quarter size of a zooecium to somewhat larger than a typical zooecium. Clear-cut evidence of monticules or maculae lacking.

In longitudinal section, zooecia extend gradually and uniformly outward to surface of zoarium which they tend to meet somewhat obliquely. Diaphragms sparse or lacking in axis, generally one-half to nearly three zooecial diameters apart in remainder of zoarium; a few zooecia show sparse diaphragms throughout. Vesicles highly elongate, irregular in shape, and loosely and haphazardly arranged; a zone, 0.5 mm. thick, of thinner crescentic vesicles extends throughout most of the zoarium and presumably reflects temporary adverse growth conditions.

Remarks.—The characteristic features of

this species are: (1) the form of the lunarium and (2) the highly irregular nature of the interzooecial tissue as observed in longitudinal section. Unlike many fistuliporoids, the vesicles do not form compact interzooecial tissue. This species is structurally unlike any described fistuliporoid of late Mississippian or early Pennsylvanian age.

Occurrence.—Amsden formation, Locality 1.

Repository.—Indiana University Paleontologic Collections; holotype 5501.

Genus DYBOWSKIELLA Waagen & Wentzel, 1886

DYBOWSKIELLA STIPATA Perry & Gutschick, n. sp.
Pl. 46, figs. 3–5

Zoarium encrusting, as much as 12 mm. thick; monticules small, slightly elevated above zoarial surface, irregularly spaced (?), and lacking zooecia.

Zooecia thin-walled, round or broadly ovate, closely spaced; most commonly four entire zooecia and portion of fifth in a distance of 2 mm.; maximum zooecial diameter (based on 20 measurements and including lunarium) ranges from 0.35 to 0.55 mm., averaging 0.42 mm.; only two of the measured zooecia exceeded 0.50 mm. in maximum diameter; adjacent zooecia commonly in contact; where not in contact, interzooecial space (based on 33 measurements) between adjacent zooecia ranges from 0.01 to 0.21 mm., averaging 0.08 mm. Lunarium prominent, generally thickened, forming a quarter or less of zooecial periphery, and commonly having extremities slightly indenting zooecial cavity; in one specimen, a few lunaria distinctly granular, having dark rod-like granules oriented perpendicular to outer boundary of lunarium. Vesicles small, subangular; typically one vesicle between adjacent zooecia where neighboring zooecia are not in contact. One ovate area, approximately 0.09 by 0.15 mm. in size, composed entirely of subangular vesicles somewhat above average in size, presumably represents monticule.

In longitudinal section, some zooecia partially recumbent near base of zoarium, later erect. Diaphragms thin, horizontal or inclined, sparse in outer third of zooecia, generally spaced a half to two zooecial diameters apart in basal two-thirds of zooecia. Vesicles small, mainly crudely rectangular, convex outward, and forming a single column between adjacent zooecia or two or more loosely interlocking columns. Two specimens show discontinuous dark lines a very short distance inside of zooecial wall which presumably represent cut ends of lunaria whose extremities have projected into zooecial cavity.

Remarks.—The distinguishing features of this species are: (1) closely spaced large zooecia, (2) small but prominent thickened lunaria which commonly indent the zooecia, and (3) the more common development of diaphragms in the basal one-half or two-thirds of the zooecia.

In the original generic description of *Dybowskiella* (Waagen & Wentzel, 1886), the authors pointed out that transitional forms most probably exist between *Fistulipora* and *Dybowskiella*. We consider that our specimens are more properly assigned to *Dybowskiella* as extremities of the lunarium definitely project into zooecia as may be observed in tangential and longitudinal section. This character of generic significance, however, is perhaps not as conspicuously developed as in other species that have been placed in *Dybowskiella* by former students.

The specific name calls attention to the disorganized crowded arrangment of the zooecia.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5502; figured paratype 5503, unfigured paratypes 5504.

DYBOWSKIELLA REGULARIS, Perry & Gutschick, n. sp.
Pl. 46, figs. 6,7

Zoarium, a sheet-like encrustation, 1.2 mm. thick, on brachiopod shell; lunaria prominent, somewhat elevated above zooecial apertures; no evidence of monticules or maculae.

In tangential section, zooecia broadly ovate, of uniform size, generally regularly and closely spaced but rarely in contact; typically four entire zooecia and portion of fifth in 2 mm.; maximum zooecial diameter, including lunarium, ranges from 0.32 to 0.35 mm., averaging 0.33 mm. for 10 meas-

urements; lunaria prominent, usually thickened, forming approximately a quarter of zooecial periphery, and having extremities that commonly project a short distance into zooecia. Adjacent zooecia typically separated by one or two, rarely three, small angular vesicles; aggregations of vesicles suggestive of monticules or maculae not observed; interzooecial distance ranges from 0.04 to 0.19 mm., averaging 0.12 mm. for 11 measurements.

In longitudinal section, zooecia erect, wall thickness uniform throughout length, and presumably lacking diaphragms. Vesicles small, regularly superposed or forming mutually interlocking columns; vesicles conspicuously larger and highly convex upward near base of colony.

Remarks.—Dybowskiella regularis is unlike any described fistuliporoid of late Mississippian or early Pennsylvanian age. The species is based on a single specimen.

The specific name directs attention to the uniform distribution or spacing of the zooecia and the regular pattern of the interzooecial tissue as observed in tangential section.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5505.

Order TREPOSTOMATA
Family STENOPORIDAE Waagen & Wentzel, 1886
Genus TABULIPORA Young, 1883
TABULIPORA AMSDENENSIS Perry & Gutschick, n. sp.
Pl. 47, figs. 1–4

Zoarium ramose, solid, zoarial fragments as much as 19 mm. in diameter and 32 mm. in length; neither monticules nor maculae observed.

In tangential section, zooecia subround to angular, thick-walled, and displaying considerable uniformity in size; typically seven entire zooecia and a portion of an eighth in 2 mm.; wall thickness generally ranges from 0.02 to 0.05 mm.; divisional line between zooecia conspicuous, obscure, or absent; within same colony, divisional line may be absent in some areas and well defined elsewhere. Acanthopores large, prominent, locally indenting zooecial cavity, and situated at junction angles of adjoining zooecia; minute black dotlike granules locally and rarely in zooecial wall between acanthopores. Areas of small zooecia, about one-half normal size or less, flanked by zooecia somewhat above average size probably represent monticules; diameter of monticule as much as 1.8 mm. but spacing not determinable. Mesopores lacking.

In longitudinal section, zooecia bend gradually from axis to interesect zoarial surface at right angles; zooecial wall thin in axis, thickening somewhat as zoarial surface is approached, and conspicuously thick locally where monilae have fused. Centrally perforate diaphragms very sparse to comparatively common (one and a half to five zooecial diameters apart) in axis but generally closely spaced (one zooecial diameter apart or less) in mature zone; inner terminations of centrally perforate diaphragms commonly somewhat bulbous. Monilae sparse and isolated in axis, well developed and either isolated or coalesced in mature region; fused and isolated monilae generally found in same zoarium. Zooecial walls consist of laminae that are acutely pointed or broadly rounded outward, the latter somewhat more common; terminations of laminae may rarely extend into diaphragms but usually material of diaphragms appears structurally independent of wall laminae.

Remarks.—Surficial zoarial features cannot be discerned as most zoarial fragments had surfaces obscured by rock matrix or had suffered extensive weathering. Isolated monilae, commonly with one or two associated diaphragms, may form a continuous zone throughout the zoarium, inclusive of axis.

Tabulipora amsdenensis is related closely to *T. carbonaria* (Worthen) and to *T. carbonaria* var. *maculosa* (Ulrich) which Ulrich (1890) recorded from the Upper Coal Measures at Caseyville, Illinois. The former differs most conspicuously from *T. amsdenensis* in lacking clusters of zooecia conspicuously smaller than average in size but flanked by zooecia somewhat larger than those in intermonticulate areas and in lacking centrally perforate diaphragms in the axis. The latter form differs from *T. amsdenensis* mainly in having somewhat larger zooecia and in lacking diaphragms in

the axis. Among Pennsylvanian stenoporoids described by Coryell (1924), *T. amsdenensis* is related most closely to *T. boggyensis* (Coryell) and *T. macalesterana* (Coryell). The Oklahoma species, however, lack or have poorly defined monticules or maculae and further differ from *T. amsdenensis* in the character of the monilae. *T. amsdenensis* clearly is distinct from *T. ohioensis* (Foerste) which has ten zooecia in a distance of 2 mm. (Foerste, 1887). Finally, *T. amsdenensis* differs in several respects from *T. ramosa* (Ulrich), an extremely abundant species in Chester (late Mississippian) rocks of the Illinois Basin.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5506, figured paratype 5507, unfigured paratypes 5508.

TABULIPORA PACHYMURALIS Perry & Gutschick, n. sp.
Pl. 47, figs. 5–7

Zoarium ramose, hollow; zoarial fragments generally less than 12 mm. in diameter and 25 mm. in length; thickness of zoarial growth usually less than 4 mm. Monticules or maculae not seen.

In tangential section, zooecia subround to angular, thick-walled, and showing considerable uniformity in size as conspicuously small zooecia rare, except in monticules; most commonly six entire zooecia and portion of seventh in two mm.; less commonly, seven entire zooecia and small part of eighth in this distance. Average wall thickness, based on 65 measurements from 13 specimens, 0.04 mm., ranging from 0.01 to 0.08 mm. Divisional line between zooecia commonly well marked, less commonly obscure and discontinuous. Locally zooecial wall appears amalgamate. Acanthopores small, dotlike, and generally at junction angles of adjoining zooecia. Minute dark granules locally and rarely in zooecial wall. Monticules probably represented by clusters of five to eight conspicuously larger zooecia or intermixed large and small zooecia; spacing of monticules not determinable.

In longitudinal section, zooecia commonly inclined or recumbent near base of zoarial growth but later becoming erect; zooecial walls thin where zooecia inclined but becoming significantly thicker outward, partially as a result of coalesced monilae Diaphragms and monilae sparse near base of zoarial growth where zooecia are inclined; centrally perforate diaphragms, generally spaced a half to one and a half zooecial diameters apart, in outer erect portion of zooecia. Monilae in outer part of zoarial growth isolated or fused to form irregularly thickened zooecial wall. Isolated and coalesced monilae commonly found in same specimen. Wall structure consists of Λ-shaped laminae whose apices are directed outward. Laminae of zooecial wall commonly not extending into centrally perforate diaphragms; rarely wall laminae obscurely continuous into diaphragms. Dark-colored minutely irregular divisional line between zooecia generally conspicuous.

Remarks.—Most specimens of this species clearly have a hollow ramose zoarium. Two other specimens are considered conspecific, although their zoarial fragments apparently form part of a sheet-like or encrusting colony. The specimens in question are identical in all respects in tangential and longitudinal section to other specimens assigned to *Tabulipora pachymuralis*. One specimen is in all probability a fragment of a normal zoarium, and the other clearly encrusts another bryozoan, most probably *T. amsdenensis*.

Tabulipora pachymuralis does not resemble any described *Tabulipora* of Pennsylvanian age. Moreover, this species differs from *T. rudis* (Ulrich), a comparatively common species of Chester (late Mississippian) age in the Illinois Basin, in having markedly smaller zooecia and less pronounced acanthopores.

The specific name directs attention to the thick-walled zooecia.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5509, figured paratype 5510, unfigured paratypes 5511.

TABULIPORA MACULATA Perry & Gutchick, n. sp.
Pl. 47, figs. 8,9; Pl. 48, fig. 1

Zoarium hollow and ramose or encrusting, the zoarial growth as much as 5 mm. thick. One low monticule observed rising very

slightly above the zoarial surface and consisting of zooecia somewhat above average in size. Acanthopores project slightly above zoarial surface as black bluntly pointed spines.

In tangential section, zooecia subround to angular and relatively uniform in size. Most commonly six entire zooecia and a portion of a seventh occupy a distance of 2 mm.; less commonly, five entire zooecia and part of sixth in this distance. Zooecial wall medium-thick to conspicuously thick within same specimen or of moderate thickness (0.01 to 0.02 mm.) throughout section. In one specimen, an area occupied by about 25 zooecia whose wall thickness ranges from 0.03 to 0.07 mm., averaging 0.05 mm., but elsewhere in this specimen wall thickness moderate, commonly 0.02 mm. Wall generally amalgamate but locally is obscurely integrate. Acanthopores large (in one specimen commonly ranging from 0.10 to 0.16 mm.), commonly inflecting zooecia, and located at junction angles of adjoining zooecia; well preserved acanthopores show minute light-colored or transparent center surrounded by dark-colored material that is encircled by a wide light colored area composed of concentrically arranged fine fibers; concentric orientation of fibers in outer band of acanthopores segregates acanthopores from zooecial wall material. Locally, and particularly in areas occupied by thick-walled zooecia, distinct minute dark granules in zooecial walls in addition to prominent acanthopores. Cluster of five zooecia somewhat above average in size presumably represents a monticule. Mesopores lacking.

In longitudinal section, zooecia very slightly inclined and thin-walled immediately above base of zoarium but erect and irregularly thick-walled in remainder of zoarium. Wall structure not entirely clear, but most probably consisting of fibers that are moderately convex outward. Diaphragms centrally perforate, commonly spaced from one to two zooecial diameters apart, but locally diaphragms may be three or possibly four zooecial diameters apart. Monilae of sporadic occurrence, lacking or poorly developed in some zooecia; elsewhere, monilae generally elongate, extending along zooecial wall for a distance equivalent to two to five zooecial diameters, with a distance of one zooecial diameter or less, in which zooecial wall is considerably thinner, separating adjacent elongate monilae. Isolated, bead-like monilae not common. A very few zooecia show nearly uniform wall thickness throughout their extent.

Remarks.—*Tabulipora maculata* is related most closely to *T. tuberculata* (Prout) which Ulrich (1890) recorded from Chester and older Mississippian rocks in Illinois. *T. maculata* differs from this species in having slightly larger and more regularly shaped zooecia, more distantly spaced and fewer centrally perforate diaphragms, and in having minute dark granules locally distributed in zooecial walls between the acanthopores. *T. maculata* differs from all tabuliporoids, showing this general zoarial form, described by Coryell (1924) in having larger zooecia.

The specific name suggests the spotted appearance of the zooecial walls when viewed in tangential section under high magnification.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5512, figured paratype 5513.

Genus STENOPHRAGMIDIUM Bassler, 1952

Bassler (1952) proposed the name *Stenophragmidium* for *Stenophragma* Munro as the latter name was preoccupied. Because, to the best of our knowledge, this genus has not hitherto been recognized in North America and thus may possibly be unfamiliar to American students, the original generic description (Munro, 1912) follows:

> "Zoarium ramose or irregular, lobate and folded; branches generally hollow and lined by an epizoarium; zooecia of varying size, the largest sometimes occupying distinct monticules at the surface; periodical thickening of the walls in the mature region well marked in many species; diaphragms present in the mature region, incomplete and very narrow, only attached to the proximal wall; acanthopores present or absent; no mesopores, but cells much smaller than the average are observed occasionally."

The type species of *Stenophragmidium*, *S. lobatum* (Munro), was collected near Ravenstonedale, Westmoreland, England, in rocks assigned to the English Carboniferous Limestone Series; the other species, *S. grandyense* (Munro), assigned by Munro to this genus

came from strata of similar age near Shop, Westmoreland. The English Carboniferous Limestone Series is late Mississippian in age as it is overlain directly by the Millstone Grit of Namurian (early Pennsylvanian) age. If the Amsden is of early Pennsylvanian age, as is widely but not unanimously held, the range of *Stenophragmidium* should be somewhat extended.

STENOPHRAGMIDIUM OBSCURUM Perry & Gutchick, n. sp.
Pl. 48, figs. 7, 8

Zoarium an uneven sheet-like encrustation, 4. mm. thick, on brachiopod shell; monticules, maculae, and acanthopores not observed externally.

In tangential section, zooecia subangular to angular, thin- to moderately thick-walled; zooecia below average in size comparatively common; seven or eight entire zooecia in a distance of 2 mm. Zooecial wall commonly integrate, less commonly amalgamate; integrate or amalgamate nature of zooecial wall determinable with difficulty in many places because of wall thinness and somewhat imperfect preservation. Acanthopores small, obscure, at junction angles of adjoining zooecia. Zooecial walls lack granules. Evidence of either monticules or maculae lacking. Mesopores absent.

In longitudinal section, zooecial wall of relatively uniform thickness throughout, except immediately above base of zoarium where zooecia are somewhat recumbent and have slightly thinner walls. Monilae poorly developed or lacking. Hemiphragms common but of sporadic occurrence. In some zooecia, hemiphragms usually a half to two zooecial diameters apart, but other zooecia have only two or three hemiphragms per zooecium. Where hemiphragms are rare, they generally are developed in basal part of zoarium. A few hemiphragms terminate in small tuberosity. Wall structure, where observable, of fine fibers that are Λ-shaped upward. This structure results in irregular dark line centrally located in zooecial wall. Under high magnification (210×), fibers forming zooecial wall material extend out into hemiphragms.

Remarks.—Stenophragmidium obscurum, which is represented in this fauna by a single specimen, differs from any described species of this genus. It can be distinguished readily in thin sections from *S. megistum* by its small obscure acanthopores and its somewhat thinner zooecial walls.

The specific name directs attention to the inconspicuous acanthopores.

Occurrence.—Amsden formation, Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5514.

STENOPHRAGMIDIUM MEGISTUM Perry & Gutchick, n. sp.
Pl. 48, figs 2–6

Zoarium a sheet-like growth, commonly encrusting brachiopod shells. Generally less than 4 mm. thick. In two specimens convoluted or twisted to form an irregular mass. Acanthopores at junction angles of adjacent zooecia and projecting as blunt spines a

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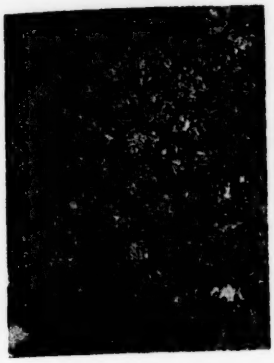
EXPLANATION OF PLATE 47

All figures ×20, except *7* which is ×60.

FIGS. *1–4—Tabulipora amsdenensis* Perry & Gutschick, n. sp., *1*, Tangential section; *2*, tangential section; *3*, tangential section showing monticule; *4*, longitudinal section showing mature zone. *1,3,4*, holotype (Ind. Univ. Paleont. Coll. 5506); *2*, paratype (Ind. Univ. Paleont. Coll. 5507); holotype and paratype from Amsden formation, Locality 2.

5–7—Tabulipora pachymuralis Perry & Gutschick, n. sp. *5*, Tangential section; *6*, longitudinal section; and *7*, longitudinal section showing structure of zooecial wall. *5,6*, holotype (Ind. Univ. Paleont. Coll. 5509); *7*, paratype (Ind. Univ. Paleont. Coll. 5510); holotype and paratype from Amsden formation, Locality 2.

8–9—Tabulipora maculata Perry & Gutschick, n. sp. *8*, Tangential section; and *9*, longitudinal section of encrusting zoarium. Holotype (Ind. Univ. Paleont. Coll. 5512) from the Amsden formation, Locality 2.



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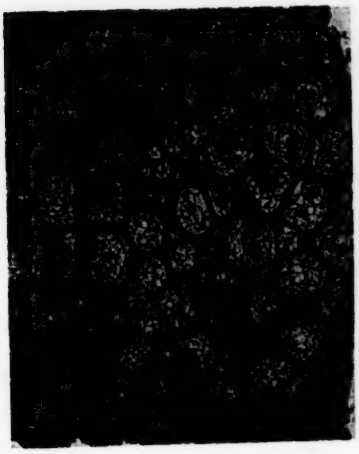

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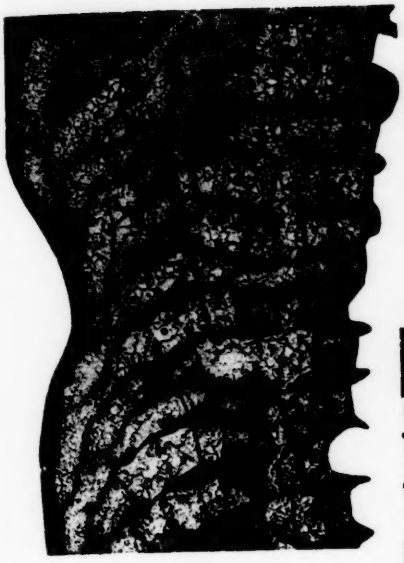

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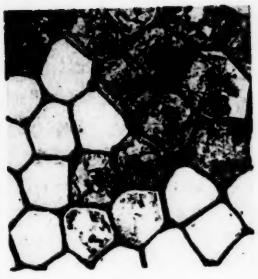

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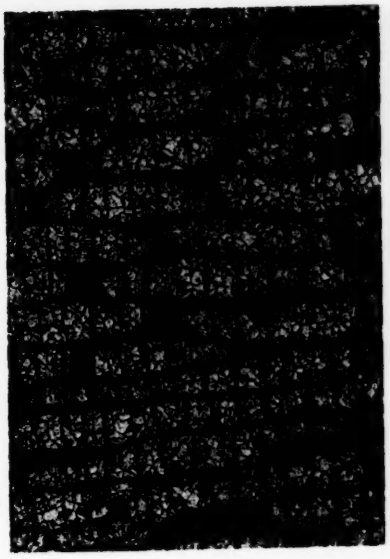

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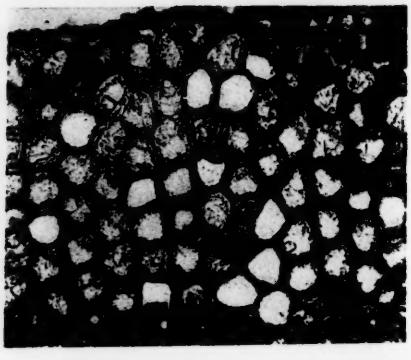

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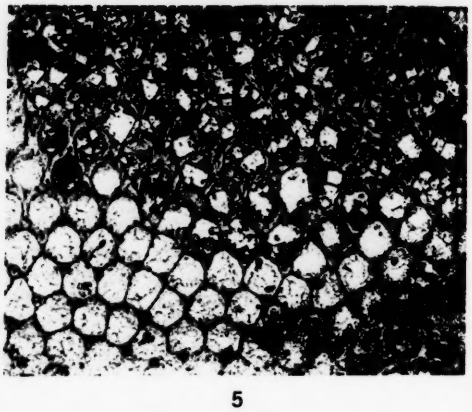

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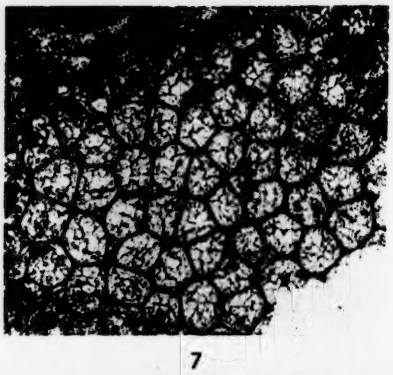

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short distance above zoarial surface. Locally zooecial wall granulose between acanthopores. Low monticules, presumably of irregular distribution, composed of zooecia somewhat above average in size.

In tangential section, zooecia comparatively uniform in size, subround to nearly angular, thick-walled to moderately thick-walled. Wall thickness typically ranges from 0.02 to 0.04 mm. but rarely 0.08 mm. Wall thickness may be highly variable within same specimen. Number of zooecia in 2 mm. shows considerable variation but typically eight entire zooecia and portion of a ninth in 2 mm. Commonly seven or nine entire zooecia in two mm. This space then generally including part of an additional zooecium. Zooecial wall usually amalgamate, homogeneous, but locally and obscurely, particularly near junction angles of adjacent zooecia, it may be integrate. Acanthopores large, commonly ranging from 0.04 to 0.07 mm in diameter, occurring at junction angles of adjoining zooecia, and usually inflecting zooecia, particularly where zooecial wall is comparatively thin. Where well preserved, acanthopore has minute hollow center, surrounded by dark-colored concentrically fibrous material that is encircled by much lighter-colored concentrically fibrous material. Commonly, acanthopore separated from zooecial wall by thin dark line. Generally two to four small but conspicuous black spots (micracanthopores ?) in zooecial wall between large acanthopores. Locally, spots may be lacking or sparsely developed. Monticules composed of five to seven zooecia about a third larger than typical zooecia. Mesopores lacking.

In longitudinal section, zooecia commonly somewhat recumbent near base, later erect. Monilae bead-like or may extend along zooecial wall for distance of one zooecial diameter or more. Where monilae well developed, adjacent monilae separated by distinctly thinner segment of zooecial wall. In exceptionally thin zoaria, zooecia usually thin-walled near base and later becoming rapidly thick-walled without distinct monilae. Zooecial wall composed of Λ-shaped laminae whose apices are moderately acute outward. Where well preserved, wall laminae extend into hemiphragms. Hemiphragms, generally fewer than five per zooecium, commonly fewer than three, and lacking or virtually absent in some zooecia. Hemiphragms locally have diaphragm-like appearance due to orientation of section.

Remarks.—The distinctive features of this species are the large prominent acanthopores and small but conspicuous black granules (micracanthopores?) that commonly are found in zooecial walls between large acanthopores. Distribution of acanthopores and granules tends to be erratic. Granules in some specimens are developed sparsely throughout the section whereas in other specimens they may be well developed locally but sparsely developed elsewhere. Similarly, granules may be clearly obvious locally, but in these areas acanthopores are conspicuous by their absence.

Variation in zooecial wall thickness within the same specimen is caused not only by variation in depth of section but is also dependent on whether the section passes through monilae or is oriented between

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EXPLANATION OF PLATE 48

All figures ×20, except *1* and *6* which are ×60

FIG. *1*—*Tabulipora maculata* Perry & Gutschick, n. sp. Tangential section showing prominent acanthopores and dark granules in zooecial walls. Paratype (Ind. Univ. Paleont. Coll. 5513) from the Amsden formation. Locality 2.

2–6—*Stenophragmidium megistum* Perry & Gutschick, n. sp. *2,3*, Longitudinal sections; *4*, tangenital section; 5, tangential section showing prominent acanthopores and abrupt variation in zooecial wall thickness; and *6*, longitudinal section showing well developed hemiphragms and monilae. *2–4*, Holotype (Ind. Univ. Paleont. Coll. 5515); *5,6*, paratypes (Ind. Univ. Paleont. Coll. 5516); holotype and paratypes from Amsden formation, Locality 1.

7–8—*Stenophragmidium obscurum* Perry & Gutschick, n. sp. *7*, Tangential section; *8*, longitudinal section. Holotype (Ind. Univ. Paleont. Coll. 5514) from Amsden formation, Locality 2.

monilae where zooecial wall is significantly thinner.

The specific name refers to the prominent acanthopores.

Occurrence.—Amsden formation, Localities 1 and 2; common at Locality 1 but rare (one specimen) at Locality 2.

Repository.—Indiana University Paleontologic Collections; holotype 5515, figured paratypes 5516, unfigured paratypes 5517.

REFERENCES

BASSLER, R. S., 1952, Taxonomic notes on genera of fossil and Recent Bryozoa: Jour. Washington Acad. Sci., v. 42, p. 381–385.

BURK, C. A., 1954, Fauna and age of the Amsden formation in Wyoming: Jour. Paleontology, v. 28, p. 1–15, 2 pls.

CORYELL, H. N., 1924, Bryozoa, *in* MORGAN, G. D., Geology of the Stonewall Quadrangle, Oklahoma: Oklahoma Bureau Geol., Bull. 2, p. 176–184, pls. 36–41.

DARTON, N. H., 1904, Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and the Rocky Mountain Front Range: Geol. Soc. America, Bull., v. 15, p. 379–448, pls. 23–36.

FOERSTE, A. F., 1887, Flint Ridge Bryozoa: Scientific Lab. Denison Univ., Bull., v. 2, pt. 1, p. 71–88, 1 pl.

GARDNER, L. S., et al., 1946, Stratigraphic sections of upper Paleozoic and Mesozoic rocks in south-central Montana: Montana Bur. Mines and Geol., Mem. 24, 100 p., 1 pl.

HENBEST, L. G., 1954, Pennsylvanian Foraminifera in Amsden formation and Tensleep sandstone, Montana and Wyoming: Billings Geol. Soc. Guidebook, 5th Ann. Field Conf.

MCMANNIS, W. J., 1955, Geology of the Bridger Range, Montana: Geol. Soc. America, Bull., v. 66, p. 1385–1430, 8 pls.

MOORE, R. C., et al., 1944, Correlation of Pennsylvanian formations of North America: Geol. Soc. America, Bull., v. 55, p. 657–706, 1 pl.

MUNRO, MADELINE, 1912, Description of some new forms of trepostomatous Bryozoa from the lower Carboniferous rocks of the North-Western Province: Quart. Jour. Geol. Soc., v. 68, p. 574–579.

SLOSS, L. L., 1946, Faunas of the Amsden and Heath formations, *in* GARDNER, L. S., et al., Stratigraphic sections of upper Paleozoic and Mesozoic rocks in south-central Montana: Montana Bur. Mines and Geol., Mem. 24, p. 6–11.

ULRICH, E. O., 1890, Paleozoic Bryozoa: Illinois Geol. Survey, v. 8, pt. 2, sec. 6, p. 285–688, pls. 29–78.

WAAGEN, WILLIAM, & WENTZEL, JOSEPH, 1886, Salt-Range fossils: Palaeontologia Indica, s. 13, v. 1, pt. 6, p. 854–892, 904–924, pls. 102–115.

WELLER, J. M., et al., 1948, Correlation of the Mississippian formations of North America: Geol. Soc. America, Bull., vol. 59, p. 91–196, 2 pls.

WILLIAMS, J. S., 1948, Mississippian-Pennsylvanian boundary problems in the Rocky Mountain region: Jour. Geol., v. 56, p. 327–351.

JOURNAL OF PALEONTOLOGY, V. 33, NO. 2, P. 323, MARCH 1959

REVIEW

A REPLY

In the Journal of Paleontology there is published in no. 2, v. 30, 1956, p. 406–411, a detailed review, written by George V. Chilingar, of my article "About dynamics of the development of septal apparatus in the ontogeny of tetracorals."

The review is very well handled and reading it gave me great satisfaction.

However, on p. 411, the author of the review permits inaccuracy which, it seems to me, cannot be left without correction.

Here it is said: "Voynovskiy-Kriger also observed that the 2nd order septa are introduced at the same four points as the septa of 1st order, and do not all form at the same time."

However, I did not so state, and such an account contradicts the true representation of the facts. I said that these septa appear "usually either suddenly around the whole periphery or at first in separate sectors of quadrants." It is said further (p. 59): "With the further growth of the coral, the number of septa of 2nd order also increases together with the increase in number of septa of 1st order. New septa of 2nd order arise, generally speaking, at *these* same four points as septa of 1st order."

In this way, only new septa of 2nd order appear at four points with the further growth of the coral; *first* septa of 2nd order, as was generally accepted up to now, all appear simultaneously, or to a lesser degree insert [themselves] in large clusters between septa of 1st order in any portion of the periphery of the coral.

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JOURNAL OF PALEONTOLOGY, V. 33, NO. 2, P. 324–332, PL. 49, 4 TEXT-FIGS., MARCH 1959

THE CLASSIFICATION OF THE MESOZOIC RHYNCHONELLOIDEA

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ABSTRACT—The various families which have been proposed for Mesozoic rhynchonelloids are re-examined. The family Dimerellidae is revised and a new family and genus are proposed for the remarkable Rhaetic brachiopod "*Rhynchonella*" *cornigera* (Schafhäutl). Internal details are given for this species and for *Sulcirostra seguenzae* (Gemmellaro) of the Dimerellidae. Three new subfamilies are proposed within the Dimerellidae.

INTRODUCTION

IN CONNECTION with the preparation of the section on Mesozoic rhynchonelloids for the "Treatise on Invertebrate Paleontology," and with work on the geographical distribution of Jurassic brachiopods in Europe, the author has investigated several little-known Alpine rhynchonelloids. Since it is intended that no important new work be included in the "Treatise," this paper is presented in advance to record the internal structures of some rhynchonelloids which differ fundamentally from the main group and to put in order the general classification.

ACKNOWLEDGMENTS

This work was made possible by the loan of specimens from the *Naturhistorisches Museum* in Vienna, through the kindess of Professor H. Zapfe; from the *Bayerischestaatssammlung* in Munich, through the kindness of Dr. W. Barthel; and from the British Museum (Natural History), through the kindness of Dr. H. M. Muir-Wood. Specimens were also collected personally in Austria whilst the author was on a traveling grant from the Hilary Bauerman bequest.

The author would like to record his thanks to Miss Elaine Bryant who prepared the photographs and serial sections, and who helped considerably in bibliographic matters.

THE EXISTING CLASSIFICATION

At the present time the classification of the superfamily Rhynchonellacea is in a most unsatisfactory state. In the most recently published general survey of brachiopod classification (Muir-Wood, 1955), only two families are listed which include Mesozoic forms—the Rhynchonellidae and the Dimerellidae. To these must be added the family Septirhynchiidae which had been proposed by Muir-Wood & Cooper four years earlier (1951). Since then, Rzhonsnitzkaia (1956) published a brief note on the classification of the rhynchonelloids, in which several new families are named, though not defined, for Palaeozoic forms. Cooper has also added several new Palaeozoic families in his mammoth work on North American Chazyan brachiopods (1956). Thus there are now 13 families named for Palaeozoic rhynchonelloids (excluding the Stenocismatacea and the Rhynchoporacea) compared with three families for the Mesozoic. This is certainly not a reflection of the relative complexity of the group in the two eras, for several of the Palaeozoic families are separated on very minor characters and the Mesozoic forms have received far less attention. It is also far from certain that some of the Palaeozoic and later families might not be synonymous. Thus the standard definition for the Rhynchonellidae as quoted by Thomson (1927) would seem to apply equally to the Camarotoechiidae. The present author would not presume, however, to revise the classification of either Palaeozoic or Cainozoic forms, which are in the hands of other workers.

THE REVISED CLASSIFICATION

It is necessary to erect one new family at this stage for the reception of an unusual Triassic form. This and the other families will be considered in turn.

Family AUSTRIRHYNCHIIDAE Ager, new family

AUSTRIRHYNCHIA Ager, n. gen.

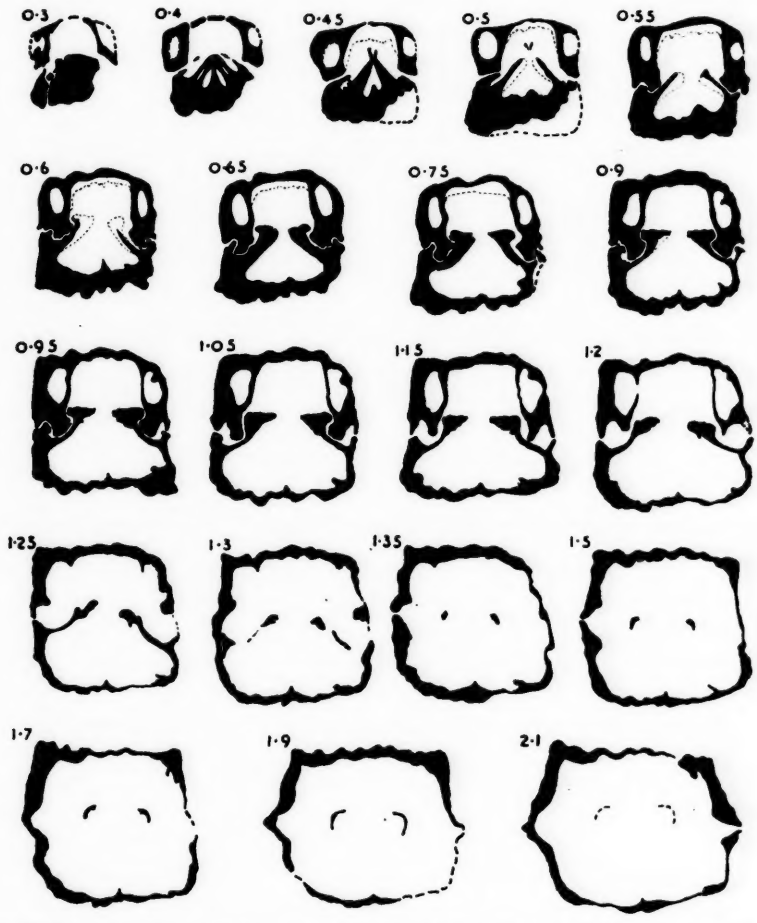
Type species: Terebratula cornigera Schafhäutl. This is the only species so far fully investigated, and its description cannot therefore be separated from that of the genus.

Diagnosis.—Small, triangular rhynchonelloid, antero-lateral angles considerably extended. Short, wide uniplication, multicostate, well-developed planareas. Dorsal septum very short with bilobed cardinal process, dorsal denticula developed, crura radulifer.

AUSTRIRHYNCHIA CORNIGERA (Schäfhautl)
Pl. 49, text-fig. 1

Terebratula cornigera SCHAFHÄUTL, 1851, Neues Jahrb. Min., Geol. und Pal., Jahrg., p. 407, pl. vii, figs. 1a–f.
Rhynchonella cornigera SUESS, 1854, Denk. k. Akad. Wiss. Wien, 7, p. 31, pl. iv, figs. 13–15.
Terebratula cornigera QUENSTEDT, p. 146, pl. x, fig. 75.

Austrirhynchia cornigera is a medium-sized subtrigonal rhynchonelloid in which the antero-lateral angles are produced to an almost incredible degree. The "wings" so formed are recurved posteriorly. Sharp beak-ridges are developed on both valves enclosing large flat or concave planareas. These



TEXT-FIG. 1—Serial transverse sections of *Austrirhynchia cornigera* (Schafhäutl) from the Upper Triassic (Rhaetian), Kössener Schichten, Hirtenberg, Austria. The figures indicate the distance of each section from the posterior and in millimeters. The original length of the specimen was 8.8 mm., but it was somewhat damaged. Author's collection J. 119/2. All $\times 4\frac{2}{3}$ approximately.

are divided by sharp ridges along the lateral commissure where the two valves meet at an acute angle. There is no perceptible interarea below the massive beak. The beak is slightly incurved with a large elliptical, hypothyrid pedicle opening. The deltidial plates are narrow and produced into a rim, i.e., in the cyclothyrid condition.

The valves are almost equally convex, and there is a low wide uniplication, though a fold is scarcely visible in the dorsal valve. The shell is somewhat flattened along the anterior commissure, and often has a rectangular appearance in anterior view (Pl. 49, fig. 3b) but for the lateral "wings." Both valves bear between 8 and 15 blunt rounded costae at the margin, of which 6 to 9 are in the uniplication. The costation extends to the unbones of both valves in unworn specimens, but nearly half the costae are secondary in origin arising directly (not as branches) between the primaries. This is well shown by Figures 1d and 2a on Plate 49. The western forms, i.e., those from Austro-Bavarian frontier area, have generally fewer costae (usually 8 to 11 on each valve), which conforms with their smaller size, though they are obviously fully developed. Costae are difficult to observe on the ' wings," which are very variable in development and consist mainly of the smooth planareas. Growth lines are not usually visible.

Internal characters are shown by serial transverse sections in Text-figure 1. Both valves are characteristically rectangular posteriorly in cross-section. In the ventral valve the delthyrial cavity is quadrate and the lateral umbonal cavities elliptical. No pedicle collar has been seen. The dental lamellae are almost parallel and directly support the massive inwardly-directed teeth. Very strong denticula are seen laterally. They are nearly as long as the teeth.

In the dorsal valve a bilobed cardinal process is developed projecting well into the ventral valve. It arises from the two thin ventrally-directed hinge-plates. The median septum is only fully developed right under the cardinal process, whence it extends anteriorly as a low ridge. There is no septalium. The sockets are anterior in position and very wide. There are no accessory sockets, but instead there are curious denticula-like processes in the dorsal valve also which project to meet the true denticula from the other valve. They may be called dorsal denticula. Anteriorly, the hinge-plates become massive and horizontal; they give rise directly to long inwardly-curved radulifer-type crura.

The following dimensions have been observed in specimens now in the British Museum (Natural History);

Length	Width	Thickness
10.0 mm.	24.8 mm.	8.1 mm.
11.4	21.8	9.2
8.6	14.5	6.7
8.8	15.5*	7.7
10.2	14.3*	7.0
11.0	18.7	8.2

* Exact width uncertain because of damage.

The above are all specimens from the eastern outcrops near Vienna.

Dr. Barthel kindly loaned the author 10 specimens from the Wendelstein area southeast of Munich. These have the following approximate dimensions:

Length	Width	Thickness
7.5 mm.	11.8* mm.	5.2 mm.
5.7	11.6	2.9
5.4	9.2	2.7
5.9	10.8	3.4
7.0	10.8*	3.5
4.9	8.3	1.2
4.4	5.7*	1.1
5.3	12.4	4.5
4.5	8.2	2.4
5.0	8.3*	1.1

* Exact width uncertain because of damage.

The smaller size of the western specimens is immediately obvious. Schafhäutl's holotype also came from here, and he gave the following measurements: length 6.5 mm., width 11.5 mm., thickness 3.9 mm.

Remarks.—The most remarkable feature of this new genus is the development of a cardinal process in a Mesozoic rhynchonelloid. Other unusual internal features are the form of the hinge-plates, the length of the denticula, and the ridges which rise to meet the denticula from the other valve. Externally the fantastic development of the "wings" is unlike anything known in any other rhynchonelloid.

The presence of a cardinal process suggests Palaeozoic affinities, but since this turns up again later in *Septirhynchia* (see below) and much later still in *Hemithiris*, it is not

thought that *Austrirhynchia* is necessarily a lone survivor from an ancient stock.

"Rhynchonella" cornaliana Bittner and *"Rhynchonella" decurtata* Girard, both from the Alpine Trias, probably also belong to this genus, but the author has seen no specimens of either species.

Occurrence.—All the specimens seen by the author came from the Eastern Alps in Austria or Bavaria. The species is best known from the Rhaetic Kössener Schichten around the type locality of Kössen on the Austro-Bavarian frontier and from equivalent strata near Piesting, between Baden and Wiener Neustadt, south of Vienna. Stratigraphically it is confined to the Rhaetic (Uppermost Triassic).

Type specimen: Dr. Barthel has informed the author (personal communication, May 1958) that the type specimen is not now preserved in Munich. It is presumed to have been lost in a fire following an air raid during the Second World War.

Family SEPTIRHYNCHIIDAE Muir-Wood & Cooper

This family was proposed by Muir-Wood & Cooper (1951) for the giant form *Septirhynchia* which had been described earlier by Muir-Wood (1935). This form has been recorded only from the Upper Jurassic of Abyssinia, Somaliland, and the Sinai Peninsula. It is remarkable for its pentameroid shape, the presence of a cardinal process in the dorsal valve, and the presence of a median septum in the ventral valve.

Septaliphoria Leidhold may also be doubtfully included here as it has a ridge-like septum in the ventral valve (Leidhold, 1920, pl. v, fig. 2d). Muir-Wood questioned this resemblance on the grounds that the septum in *Septirhynchia* is developed differently.

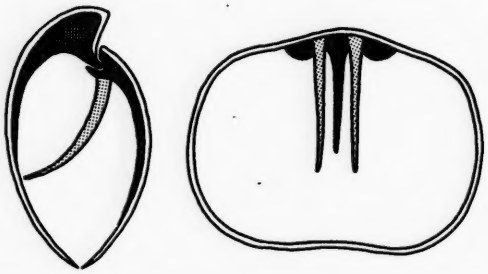
Family DIMERELLIDAE Buckman

This family was erected by Buckman (1918) for seven genera: *Dimerella* Zittel, *Rhynchonellina* Gemmellaro, *Rhynchonellopsis* Böse, *Cryptopora* Jeffreys, *Hemithiris* d'Orbigny, and two new genera of his own: *Cardinirhynchia* and *Rectirhynchia.*

Of these, *Cryptopora* was separated by Muir-Wood (1955) as a new family Cryptoporidae. *Cryptopora* differs fundamentally in its anatomy from other living rhynchonelloids. *Hemithiris* was only doubtfully included by Buckman and was returned to the Rhynchonellidae by Thomson (1927). Rzhonsnitzkaia (1956) named a new subfamily of Rhynchonellidae the Hemithyrinae. *Cardinirhynchia* was included here by Buckman merely because of its straight hinge-line and large foramen. It appears to have no essential characters in common with *Dimerella*, the type genus, and is best kept with the Rhynchonellidae for the present.

Rhynchonellopsis Böse was provisionally proposed (1894) for a *Rhynchonellina*-like form from the Upper Jurassic in case it should prove to have similar long crura. Cooper & Muir-Wood (1951) pointed out that it was a junior homonym of *Rhynchonellopsis* Vincent, and they renamed it *Capillirostra.* However, it is almost certainly a juvenile form and may have no connection with the other genera listed above. In the same paper, Cooper & Muir-Wood substituted *Sulcirostra* for another homonym—*Rhynchonellopsis* Di Gregorio. This was a simple subdivision of Gemmellaro's genus *Rhynchonellina* and is obviously closely related to it.

Rhynchonellina was first described by Gemmellaro from the Lias of Sicily (1876). A large amount has been written about it, most notably the detailed study by Böse (1894). There is obviously considerable variation within this genus and the related genus *Sulcirostra.* Externally they range from completely smooth forms such as the type species of *Rhynchonellina—R. seussi* Gemmellaro—to forms with a strong radial ornament such as the type species of *Sulcirostra—S. seguenzae* (Gemmellaro). There are also considerable internal differences, notably in the presence or absence of accessory falciform processes at the base of the crura and in the development of the dorsal median septum. In his original description, Gemmellaro expressed doubts about the existence of a median septum in many species of *Rhynchonellina*, though he observed it in the type species. Böse was more dogmatic; he said it was present in most species and illustrated it as a low ridge in his reconstruction (see Text-fig. 2). One unusual feature which all these forms have in common is the extreme length of the



TEXT-FIG. 2—Reconstruction of the interior of *Rhynchonellina*. Left: lateral view. Right: ventral view of dorsal valve. After Böse, 1894.

crura, which curve round and almost touch the ventral valve.

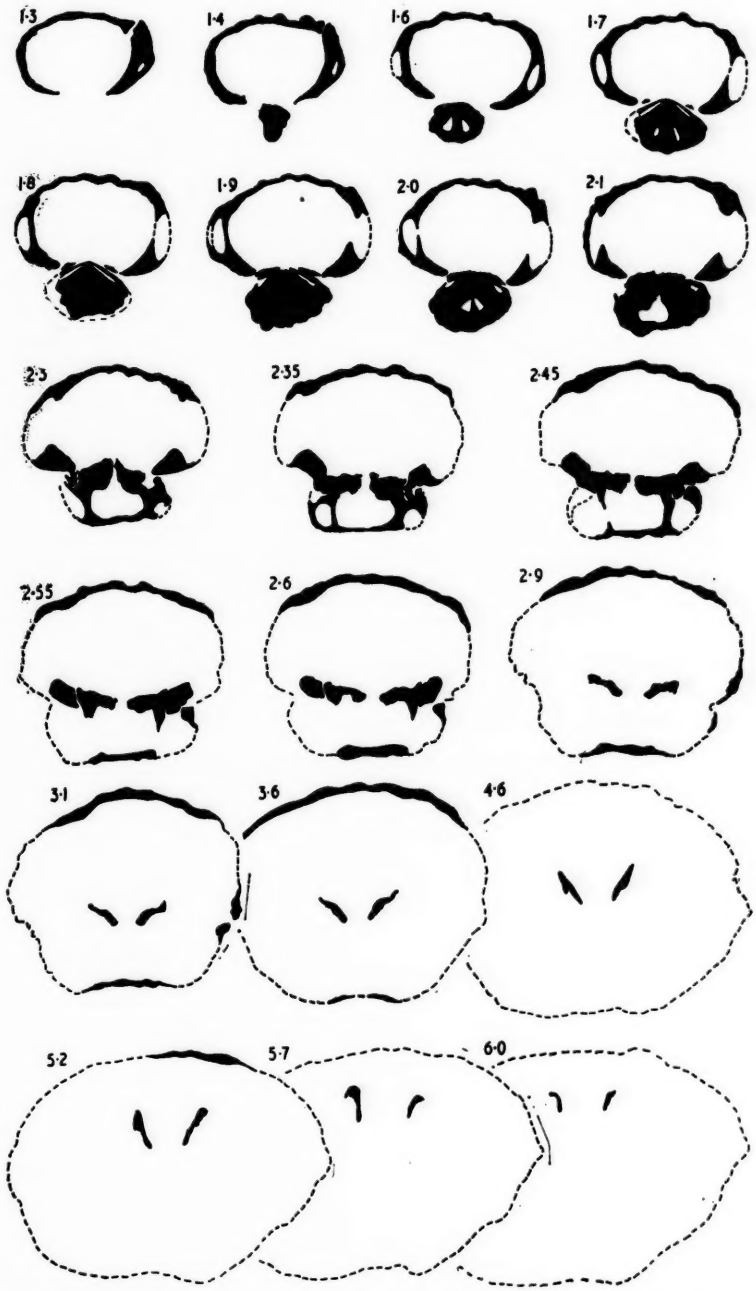
In connection with the "Treatise" work, a specimen of *Sulcirostra seguenzae* (Gemmellaro)—the type species—was sectioned. A number of the sections are shown in Text-figure 3 as a record of this little known genus and for comparison with sections of more "normal" rhynchonellids. Like the majority of Alpine brachiopods, it was not really suitably preserved for sectioning, being much recrystallized, but it shows the essential features of the group.

The form of the delthyrial and umbonal cavities is exactly like that figured by Böse for *Rhynchonellina*. There is no septalium in the dorsal valve and the septum is very short. The most noteworthy features are the very long crura (seen in the bottom two rows of sections), the very massive hinge-plates (seen in the third and fourth row), and the two lamellae supporting the hinge-plates (seen in the third row). These lamellae appear to be unique among Mesozoic rhynchonelloids. They presumably strengthened the sockets, though it is curious that the teeth in the other valve are not supported at all by the dental lamellae. They were mentioned by Böse but have not previously been figured.

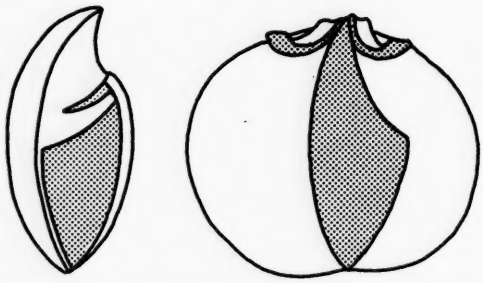
The next and most important point to be considered is the relationship between the *Rhynchonellina* group and the type genus of the family—*Dimerella*. The latter, unfortunately, is not very well known. It was described and figured by Zittal (1870) and is like *Rhynchonellina* s.l. in general characters, but differs most notably in the presence of a masive dorsal septum. This septum rises anteriorly and forms a complete partition across the shell. The crura in *Dimerella* are long, but not so long as in *Rhynchonellina*, and are more sharply curved towards the ventral valve. Two reconstructions of the inside of the shell in *Dimerella* are shown in Text-figure 4 for comparison with *Rhynchonellina*. There appears to be no reasonable objection to including these forms in the one family, separate from the Rhynchonellidae. The only regret is that *Rhynchonellina* was not made the type genus rather than *Dimerella*.

All the genera so far accepted in this family are either always sulcate or include a large proportion of sulcate species. They are also frequently of very small size and are "Tethyan" in distribution. This leads one naturally to the other genera here included in the same family. The only other genus included by Buckman was *Rectirhynchia* which is a tiny smooth form of which no internal details are known. It has a large delthyrium like *Dimerella* and is strongly sulcate (that is to say it has a strong fold in the ventral valve and a sinus in the dorsal). It seems logical to connect this directly with three other genera—*Norella* Bittner, *Aprigia* Di Gregorio, and *Pisirhynchia* Buckman. All of these are minute, smooth, sulcate forms and may in fact be synonymous. They differ from *Rectirhynchia* in their incurved beaks and small delthyria.

In his classic work on the Jurassic brachiopods, Buckman (1918) placed great emphasis on what he called the "*Norella* stage" in the development of rhynchonellids. This work was done in the heyday of recapitulatory theories, and he based his classification and lineages on the idea that the ancestral rhynchonellid was sulcate or "norelliform." Thus, from a "primitive" sulcate form such as *Norella* he dervied forms in which the norelliform phase was restricted to the earlier growth stages and thence by a process of lipopalingenesis he derived the "normal" uniplicate forms in which the norelliform stage was omitted. However, this beautiful theory does not stand up to critical examination. In several genera, Buckman recognized a norelliform stage which is not apparent to other workers. Thus he made it an essential criterion of his genus *Tropiorhynchia* (1918) but there is no trace



TEXT-FIG. 3—Serial transverse sections of *Sulcirostra seguenzae* (Gemmellaro) (=*Rhynchonellina juvavica* Bittner) from the Lias, Ramseider-scharte, Steinernen Meeres, Austria. The figures indicate the distance of each section from the posterior end. The original length of the specimen was 13.5 mm. Author's collection J. 1120/1. All 3½ approximately.



TEXT-FIG. 4—Reconstruction of the interior of *Dimerella* for comparison with Text-fig. 2. Left: lateral view. Right: oblique ventral view of dorsal valve. After Zittel, 1870.

of it in his type species *T. thalia* (d'Orbigny). This point has been checked in the holotype at the *Museum d'histoire naturelle* in Paris.

The present author prefers to regard this group of small, smooth, sulcate forms as a separate branch of rhynchonelloids which evolved independently in the Tethyan region during early Mesozoic types. In the absence of internal data, their relationship to *Dimerella* cannot be proved, but the many external similarities and the similarity in distribution make it probable. Furthermore, there are two connecting links between the two groups. One is the genus *Carapezzia* Tomlin (1930) which was proposed as a *nom. nov.* for *Geyeria* Carapezza & Schopen (*non Geyeria* Buchecker, 1876). The latter was erected as a subgenus of *Rhynchonellina* based on Liassic material from Sicily (Carapezza & Schopen, 1899). This is clearly close to *Rhynchonellina* with the very long crura, but has the incurved beak and small delthyrium of the *Norella* group. The second connecting link is provided by the sulcate genus *Septocrurella*. This was well described by Wišniewska (1932) and illustrated with some of the first serial transverse sections. It closely resembles *Norella* and the others in general characters but is notable internally for the absence of a dorsal median septum and the presence of what Wišniewska calls *plaques crurales* supporting the hinge-plates. These are exactly comparable to the plates described above in *Sulcirostra* (Text-fig. 3) and mentioned by Böse in *Rhynchonellina*. It may be presumed that the long crura and high septum of the Triassic and early Liassic were reduced and lost by the time *Septocrurella* had evolved in the Upper Jurassic.

For convenience, three subfamilies are proposed to cover the three groups just discussed.

Subfamily **Dimerellinae** Ager, *nov.*: small forms with a very strong dorsal median septum: *Dimerella*.

Subfamily **Rhynchonellininae** Ager, *nov.*: forms with little or no median septum and excessively long crura: *Rhynchonellina Capillirostra*(?), *Sulcirostra*.

Subfamily **Norellinae** Ager, *nov.*: minute forms with small delthyria: *Norella*, *Apringia*, *Pisirhynchia*, *Rectirhynchia*, *Carapezzia*, *Septocrurella*.

Four other genera should be mentioned at this point and provisionally (though rather doubtfully) included in the last subfamily. Two of these are Buckman genera—*Holcorhynchia* and *Gnathorhynchia*—both of which are small, smooth, and rectimarginate but with a dorsal sinus posteriorly. The third is *Austriellula* Strand (=*Austriella* Bittner) which is a small smooth form without a sinus in either valve, but Tethyan in distribution. The fourth is *Monticlarella* Wisniewska which is an Upper Jurassic form with a posterior dorsal sinus like *Holcorhynchia* but finely capillate.

The concentration of small inverted (i.e., sulcate) rhynchonellids in the Tethyan province is particularly interesting. They occur in Sicily, the Apennines, and the Alpine region but are practically unknown elsewhere. Apart from *Holcorhynchia* and *Gnathorhynchia* (which are in any case both doubtful and rare), the Dimerellidae as here defined are virtually unknown in the British record, though Buckman did record a very rare *Norella* in the British Bajocian (1910). They may extend as far as central Turkey (with *Rhynchonellina anatolica* Vadasz) but this is an isolated form and brachiopod distributions in southeast Europe are little known. They are accompanied throughout the Tethyan province by sulcate terebratulids, which are similarly rare elsewhere. It must be presumed that this particular shell shape was in some way suited to the Tethyan environment.

Family RHYNCHONELLIDAE Gray

This family can still be regarded as including the vast majority of the Mesozoic

rhynchonelloids. The type genus was recently revised by the present author on the basis of topotype material of the type species *Rhynchonella loxia* Fischer (Ager, 1957). This was shown to be typical of the group in its internal characters, though somewhat atypical in its external appearance. The main stock of rhynchonellids in the Jurassic may be said to pass through forms such as *Tetrarhynchia* and *Goniorhynchia*, which are generalized in both internal and and external characters.

Only two subfamilies have so far been proposed for the Mesozoic rhynchonellids. These are Rhynchonellinae Gill and Acanthothyrinae Schuchert. The latter was criticized by Buckman (1918) and Thomson (1927) as an artificial association of spinose forms coming from different stocks. Several new subfamilies, based on internal characters, could be proposed to link related genera, but these would at present leave only a large unsatisfactory residue of forms which could not be placed in the classification.

The most distinctive criteria in the Mesozoic Rhynchonellidae seem to be the form of the crura, the hinge-plates, the dorsal median septum, and the deltidial plates. The early Mesozoic forms all appear to have the simplest (radulifer) type of crura (Ager, 1956). More complex types, such as the falcifer crura of *Stolmorhynchia*, appeared only in the Middle Jurassic. Later, other groups were differentiated, for example, the *Lacunosella-Orbirhynchia* group of the Upper Jurassic and Cretaceous, which have falcifer crura but no septa, and the *Cyclothyris* group of the Cretaceous, including the genera recently described by Burri (1956), which have cyclothyrid deltidial plates and distally concave crura. Such groups should, in due course, be defined as subfamilies, but as they are clearly offshoots of the main *Rhynchonella* stock, they should not be given higher rank.

CONCLUSIONS

The following provisional classification is therefore proposed for Mesozoic rhynchonelloids. The definitions given are merely for guidance and are not meant to be complete.

Suborder **Rhynchonelloidea** Moore, 1952 (*nom. transl.*). Articulate brachiopods in which the delthyrium is partly closed by deltidial plates and the lophophores are usually supported by crura.

Superfamily **Rhynchonellacea** Schuchert, 1896. Rhynchonelloids with impunctate shells, without spondylia.

Family **Rhynchonellidae** Gray, 1848. Rhynchonellacea without a prominent dorsal septum and with short crura (Thomson, 1927). Anterior margin rectimarginate or uniplicate, no cardinal process. Distribution general.

Family **Dimerellidae** Buckman, 1918. Tethyan Rhynchonellacea, usually sulcate and very small, with deltidial plates often reduced, very long crura, dorsal septum sometimes prominent.

Family **Septirhynchiidae** Muir-Wood & Cooper, 1951. Giant East African Rhynchonellacea with cardinal process in dorsal valve and median septum in ventral valve.

Family **Austrirhynchiidae** Ager, *nov.* Tethyan Rhynchonellacea with cardinal process, dorsal denticula and shell extremely expanded laterally.

REFERENCES

AGER, D. V., 1956, A Monograph of the British Liassic Rhynchonellidae, Part 1: Paleontogr. Soc. (Monogr.) i–xxxvi, p. 1–50, pls. I–IV.

——, 1957, The True *Rhynchonella:* Palaeontology, v. 1, (1), p. 1–15, 2 pls.

BÖSE, E., 1894, Monographie des Genus *Rhynchonellina* Gemm.: Palaeontographica, v. 41, p. 49–80, pls. vi, vii.

BUCKMAN, S. S., 1910, Certain Jurassic (Inferior Oolite) species of ammonites and Brachiopoda: Quart. Jour. Geol. Soc. London, v. 46, p. 90–110, pls. ix–xii.

——, 1918, The Brachiopoda of the Namyau beds, Northern Shan States, Burma: Palaeont. Indica, N.S. 3, (2), 1917, 299 p., 21 pls.

BURRI, F., 1956, Die Rhynchonelliden der Unteren Kreide (Valanginien-Barremien) im westschweizerischen Juragebirge: Eclog. geol. Helvet., v. 49, p. 599–701, 15 pls.

CARAPEZZA, E., & SCHOPEN, L. F., 1899, Sopra alcune nuove rhynchonellina della Sicilia: Giorn. Sci. Nat. Econ. Palermo, v. 22, p. 215–251, 4 pls.

COOPER, G. A., 1956, Chazyan and related brachiopods: Smithson. Misc. Coll., 127 p., i–xvi, 1–1245, 269 pls.

COOPER, G. A. & MUIR-WOOD, H. M., 1951, Brachiopod homonyms: Jour. Washington Acad. Sci., v. 41, p. 195, 196.

GEMMELLARO, G. G., 1876(?), Studi paleontologici sulla fauna del calcare a *Terebratula Janitor* del Nord di Sicilia, Parte III, Palermo: p. 1–100, pls. I–XIII. (Dated 1871, but includes references to literature published in 1874 and 1875.)

LEIDHOLD, C., 1920, Beitrag zur genauren Kenntnis und Systematik einiger Rhynchonelliden des reichsländischen Jura.: Neues Jahrb. Min., Geol. und Palaeont., Beil.-Bd. 44, p. 343–368, pls. iv–vi.

MUIR-WOOD, H. M., 1935, Jurassic Brachiopoda (in The Geology and Palaeontology of British Somaliland), (2), p. 75–147, pls. vii–xiii, London.

——, 1955, A History of the classification of the phylum Brachiopoda: British Museum (Nat. Hist.) London, 1955, p. 1–124.

MUIR-WOOD, H. M. & COOPER, G. A., 1951, A new species of the Jurassic brachiopod genus *Septirhynchia:* Smithson. Misc. Coll. 116, (6), p. 1–6, pls. i, ii.

QUENSTEDT, F. A., 1871, Petrefactenkunde Deutschlands, 2, Brachiopoden: pls. xxxvii–lxi, Leipzig.

RZHONSNITZKAIA, M. A., 1956, Systematisation of Rhynchonellida: Resumenes de los Trabajos Presentados, XX Congreso Geologico Internacional, p. 125, 126.

SCHAFHÄUTL, K. E. F. VON, 1851, Über einige neue Petrefakten des Sudbayern'schen Vorgebirges: Neues Jahrb. Min., Geol. und Paläont., Jahrg., p. 407–421, pl. vii.

SUESS, E., 1854, Uber die Brachiopoden der Kössener Schichten: Denkschr. k. Akad. Wiss. Wien, 7, p. 29–65, pls. i–iv.

THOMSON, J. A., 1927, Brachiopod morphology and genera (Recent and Tertiary): New Zealand Board Sci. Art. Manual, v. 7, 338 p., 2 pls.

TOMLIN, J. R. LE B., 1930, Some preoccupied generic names, II: Proc. Malac. Soc. London, v. 19, p. 22–24.

WIŚNIEWSKA, M., 1932, Les Rhynchonellides du Jurassique sup. de Pologne: Palaeont. Polon., v. 2, p. 1–71, pls. i–vi.

ZITTEL, K. A., 1870, Ueber den Brachial-Apparat bei einigen jurassischen Terebratuliden und über eine neue Brachiopodengattung *Dimerella:* Palaeontographica, v. 17, p. 211–224, pl. xli.

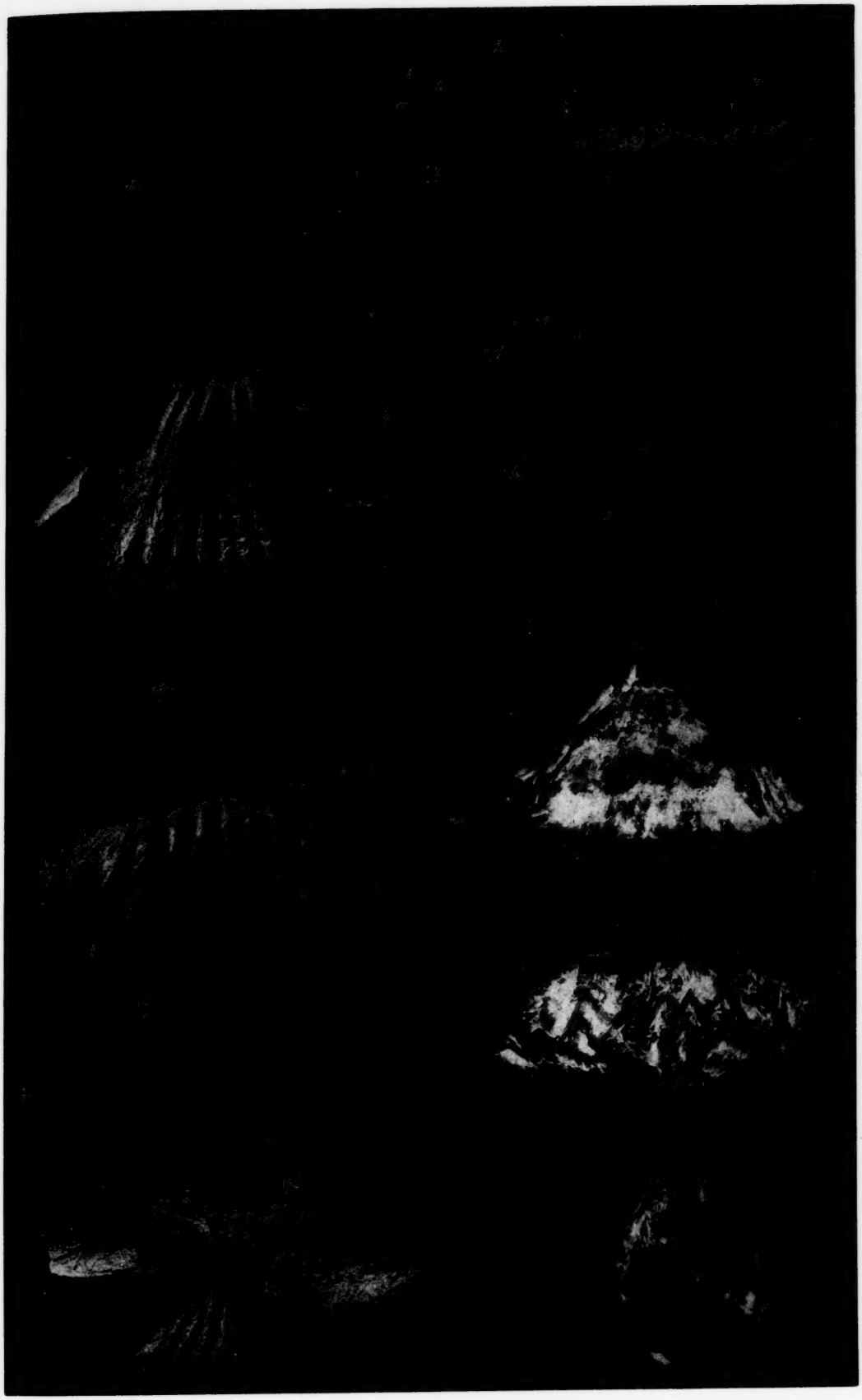
EXPLANATION OF PLATE 49

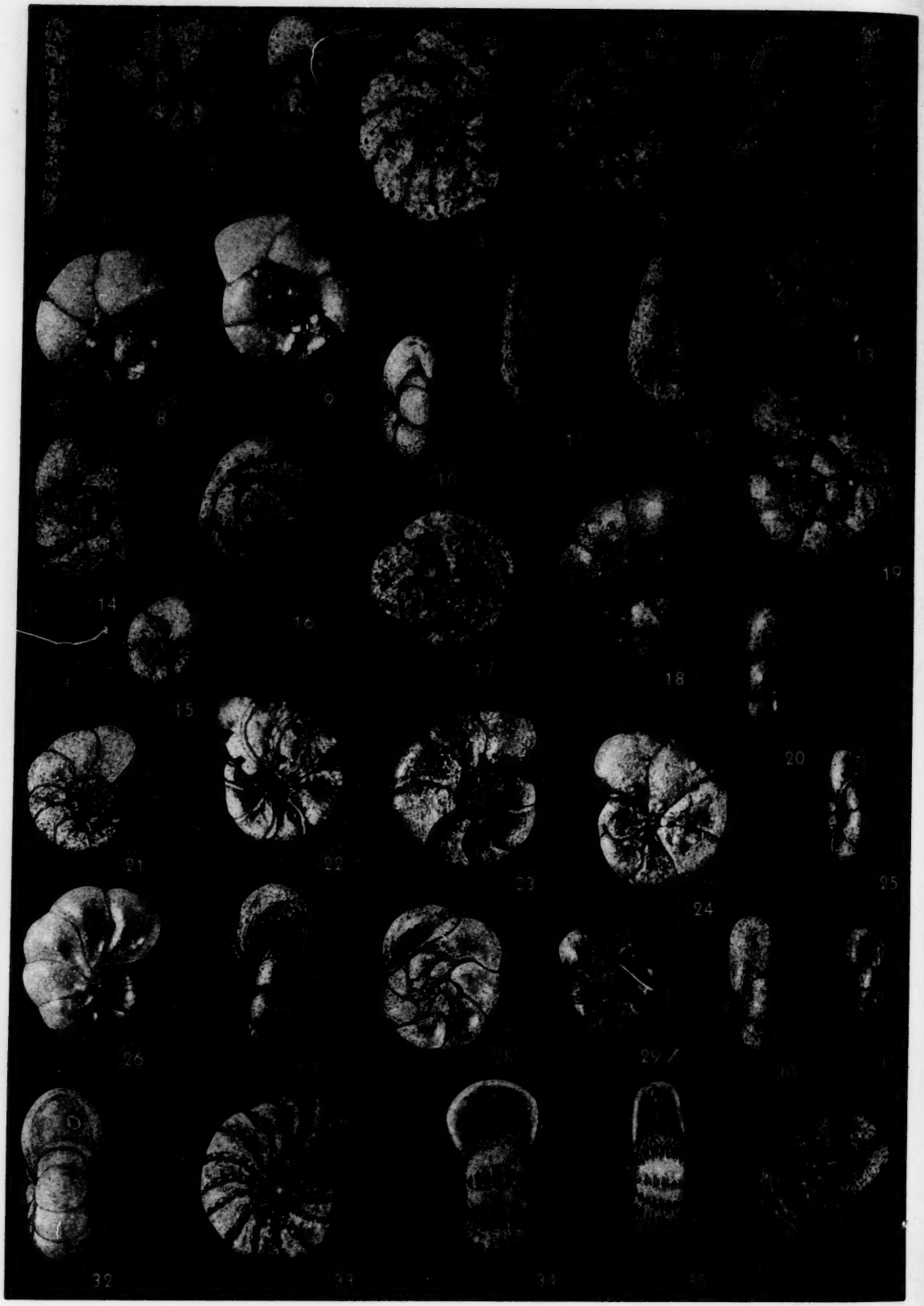
In each case *a* is the dorsal view, *b* the anterior view, *c* the lateral view, and *d* the posterior view.

FIG. *1d—Austrirhynchia cornigera* (Schafhäutl). An exceptionally well-preserved specimen with both "wings." Kössener Schichten (Rhaetic), Starhemberg near Piesting, Austria. Specimen in the British Museum (Natural History), register no. BB 20442. ×4.

2a–2d—Austrirhynchia cornigera (Schafhäutl). A specimen with one wing very well preserved, the other broken. Same horizon, locality, and collection, register no. BB 20443. ×4.

3a–3c—Austrirhynchia cornigera (Schafhäutl). This specimen was not coated with ammonium chloride before photographing, and shows the normal appearance of the shell. *3b* shows clearly the rectangular appearance of the species in anterior view. Kössener Schichten, Hirtenberg, Austria. Specimen in the *Naturhistorisches Museum*, Vienna, register no. J. 1119/1. ×4.

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JOURNAL OF PALEONTOLOGY, V. 33, NO. 2, P. 333–343, PL. 50, 5 TEXT-FIGS., MARCH 1959

ECOLOGY OF MARSH FORAMINIFERA IN POPONESSET BAY, MASSACHUSETTS

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ABSTRACT—Distributions of the species of Foraminifera (living and dead) forming the greater part of the foraminiferal faunas in marshes in Poponesset Bay, Massachusetts, have been studied. Eight stations were sampled bimonthly for one year (August, 1956 to September, 1957). The marsh environments vary from almost non-marine (with tidal influence) to near marine. *Arenoparrella mexicana*, *Haplophragmoides hancocki*, *Tiphotrocha comprimata*, and *Trochammina macrescens* decrease with increasingly marine conditions, whereas *Jadammina polystoma* and *Trochammina inflata* increase. Other species such as *Ammobaculites dilatatus*, *Ammotium salsum*, *Miliammina fusca*, and *Protelphidium tisburyense* fluctuate independently of the degree of brackish or marine conditions. Unknown factors governing micro- and macroenvironments probably play an important part in controlling distributions. Suggested factors are type of vegetation, chemical factors, pH, nutrients and food. Calcareous specimens are rapidly destroyed after death presumably due either to the ability of the living form to resist acidity or to a postulated increase in acidity immediately below the sediment surface, more probably the latter. This destruction of the tests is of importance in the interpretation of ancient marsh environments. Many species, including the calcareous ones, had their largest living populations in June or September and their smallest in December or February. There were some exceptions such as *Miliammina fusca* which showed an increase in winter. The total living populations were greatest in June and lowest in December, which may be related to maximum temperature and time of greatest reduction in temperature respectively. Multiple sampling showed that distributions at any one station were fairly uniform although nearby samples in different microenvironments in some cases vary considerably.

EXPLANATION OF PLATE 50

All illustrations were photographed and retouched by the senior author.

FIG. *1*—*Reophax* sp. Station 7. USNM 626397, ×58.

2,3—*Haplophragmoides hancocki* Cushman & McCulloch. *2*, Side view, USNM 626384; and *3*, apertural view, USNM 626385, ×58. Station 2.

4,5—*Ammobaculites dilatatus* Cushman & Bronnimann. Side views, USNM 626373, 626374, ×45. Station 2.

6,13—*Ammotium salsum* (Cushman & Bronnimann). Side views, USNM 626375, 626376, ×58. Station 8.

7—*Textularia earlandi* Parker. USNM 626398, ×58. Station 6.

8-10—*Arenoparrella mexicana* (Kornfeld). *8,9*, Side views, USNM 626377, 626378; and *10*, apertural view, USNM 626379, ×58. Station 2.

11,12—*Miliammina fusca* (Brady). Side views, USNM 626389, 626390, ×45. Station 1.

14-17—*Tiphotrocha comprimata* (Cushman & Bronnimann). *14,16*, Dorsal view, USNM 626399, 626401; and *15,16*, ventral views, USNM 626400, 626402, ×45. Station 1.

18-20—*Trochammina inflata* (Montagu). *18*, Ventral view, USNM 626404, ×45; *19*, dorsal view, USNM 626403, ×58; and *20*, edge view, USNM 626405, ×45. Station 3.

21,22,27—*Jadammina polystoma* Bartenstein & Brand. *21*, Dorsal view, USNM 626386; *22*, ventral view, USNM 626387; and *27*, edge view, USNM 626388, ×58. Station 8.

23-25—*Trochammina macrescens* Brady. *23*, Dorsal view, USNM 626406; *24*, ventral view, USNM 626407; and *25*, edge view, USNM 626408, ×45. Station 1.

26,32—*Protelphidium tisburyense* (Butcher). *26*, Side view, USNM 626391; and *32*, apertural view, USNM 626392, ×58. Station 2.

28-31—*Pseudoeponides anderseni* Warren. *28*, Dorsal view, USNM 626393; *29*, ventral view, USNM 626394; and *30,31*, edge views, USNM 626395, 626396, ×58. Station 6.

33-35—*Elphidium galvestonense* Kornfeld. *33*, Side view, USNM 626380; and *34,35*, apertural views, USNM 626381, 626382, ×45. Station 5.

36—*Elphidium gunteri* Cole. Side view, USNM 626383, ×58. Station 2.

INTRODUCTION

THE purposes of this study were: 1, to investigate the distribution of Foraminifera in marsh environments of varying salinity from almost fresh (with tidal effect) to nearly normal marine and 2, to study the seasonal numerical variation of living specimens of the various species. Eight stations along the marshy shores of Poponesset Bay from the mouth of the narrow portion of the Cotuit River to Meadow Point were sampled bimonthly from August, 1956, to September, 1957. Duplicate samples were taken occasionally to check the reliability of the samples and triplicate samples were taken at the final collection. Salinity and temperature were measured each time of sampling. This study was supported by the University of California under contract with the Office of Naval Research and by the Woods Hole Oceanographic Institution. James R. Moriarty drafted the text figures. Miss Ruth Todd kindly compared specimens of *Ammobaculites dilatatus* with the types.

This is Marine Foraminifera Laboratory Contribution no. 27, Scripps Institution of Oceanography Contribution, New Series, and Woods Hole Oceanographic Institution Contribution no. 971.

DESCRIPTION OF THE AREA

Poponesset Bay is situated on the south side of Cape Cod, Massachusetts, extending roughly from Lat. 41°35′ N to Lat. 41°37′ N and Long. 70°27′ W to Long. 70°28′ W. The upper part of the bay is charted as the Cotuit River but in this study the river is more rigorously defined as the narrow stream draining into the bay at the northern end. The collecting stations (Text-fig. 1) are situated along the eastern shore of the bay from the river mouth to a small marsh east of Meadow Point. The latter is almost directly exposed to the open water of Nantucket Sound owing to the comparatively recent opening of a large gap through the sand spit (Poponesset Beach) which formerly cut this area off from the open sound to the southeast and east. This sand spit and opening are not illustrated since no accurate survey is available.

STATIONS

Eight stations were sampled at approximately bimonthly intervals from August, 1956, to September, 1957. At various times duplicate samples were taken and, at the last collection, triplicate ones. The following is a general description of the environment of each station, including maximum and minimum temperatures and salinities encountered during the collecting period, and the foraminiferal species comprising the major part of the faunas (living plus dead). These temperature and salinity values may not necessarily reflect the extremes which occurred during this interval since the sampling times may not have coincided with them. At no time of sampling was any locality frozen solid although in February there was a thin skin of ice at stations 4, 5, and 8.

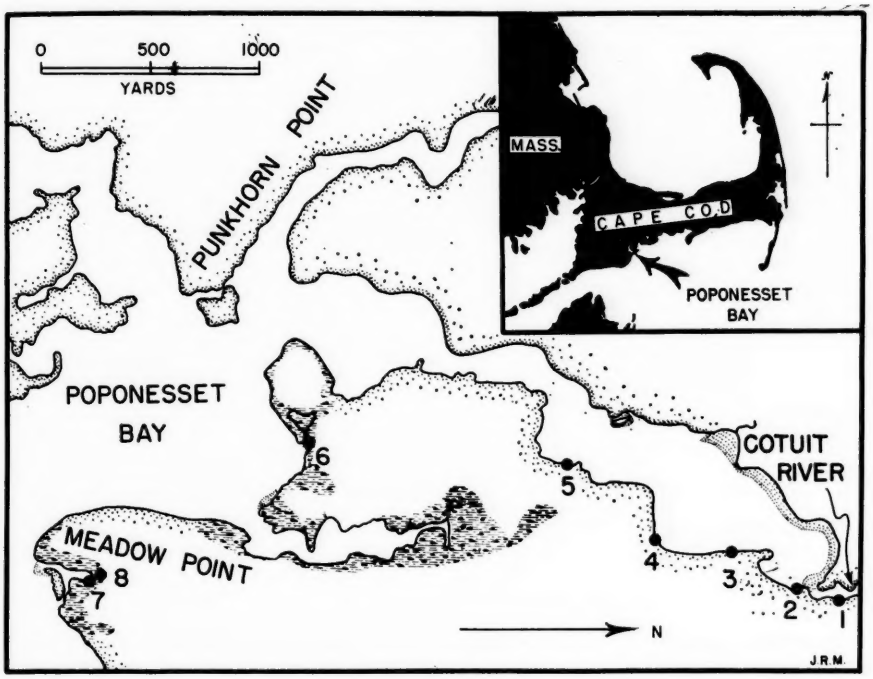
Station 1. In *Zostera* on high marsh submerged only at high tide. Located slightly above the river mouth. 1.5°C. (Feb.) to 24°C. (Aug.), salinity 0.6–21.6 °/₀₀. This maximum salinity was observed only once, salinities otherwise did not exceed 9.9 °/₀₀. *Miliammina fusca, Tiphotrocha comprimata,* and *Trochammina macrescens* comprise 91% of the fauna.

Station 2. Muddy bank at edge of *Zostera* growth, submerged at mid-tide. Located slightly below the river mouth. 4.5°C. (Dec.) to 26°C. (June), salinity 1.8–28.2 °/₀₀. *Ammotium salsum, Arenoparrella mexicana, Miliammina fusca, Protelphidium tisburyense, Tiphotrocha comprimata,* and *Trochammina macrescens* comprise 90% of the fauna.

Station 3. Zostera marsh exposed at low tide. 3°C. (Feb.) to 22°C. (Aug.), salinity 4.2–20.6 °/₀₀. *Arenoparrella mexicana, Miliammina fusca, Tiphotrocha comprimata,* and *Trochammina inflata* comprise 88% of the fauna.

Station 4. Shallow pool in *Zostera* growth about one foot above low tide level. This station was not sampled until December. 1°C. (Feb.) to 22.5°C. (Sept.), salinity 6.2–23.9 °/₀₀. *Ammotium salsum, Arenoparrella mexicana, Miliammina fusca, Protelphidium tisburyense, Tiphotrocha comprimata,* and *Trochammina macrescens* comprise 93% of the fauna.

Station 5. Shallow pool (1–4 inches deep) in high marsh behind *Zostera* growth. 1°C. (Feb.), to 32°C. (June), salinity 4.5–24.2 °/₀₀. *Ammotium salsum, Jadammina polystoma, Protelphidium tisburyense, Tiphotrocha comprimata,* and *Trochammina inflata* comprise 92% of the fauna.



TEXT-FIG. *1*—Location of stations.

Station. 6. High *Spartina* marsh exposed except at high tide. 3.6°C. (Dec.) to 29.5°C. (June), salinity 24.8–28.2 °/₀₀. *Ammotium salsum, Jadammina polystoma, Miliammina fusca,* and *Trochammina inflata* comprise 88% of the fauna.

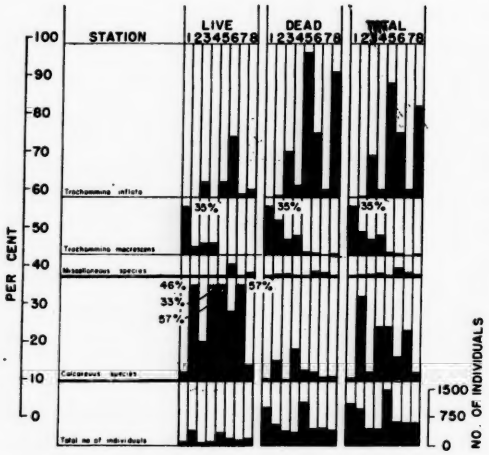
Station 7. High *Zostera* marsh exposed except at high tide. 0.2°C. (Feb.) to 29°C. (June), salinity 23–34.3 °/₀₀. *Ammotium salsum, Miliammina fusca,* and *Protelphidium tisburyense* comprise 90% of the fauna.

Station 8. Inner (landward) end of long, narrow high marsh in shallow pool or channel (1–6 inches deep), isolated except at high tide and not flushed by every tide. 0.2°C. (Feb.) to 30°C. (Aug., June), salinity 26.5–45.2 °/₀₀. The salinity only reached this high value at one time of sampling, otherwise the maximum was 35.8 °/₀₀. *Ammotium salsum, Jadammina polystoma,* and *Trochammina inflata* comprise 88% of the fauna.

In most places the highest temperatures were registered in June, the lowest in February. The salinity changes did not follow any regular seasonal pattern probably due to the many factors involved such as tidal influence, rainfall, seepage, evaporation, etc. Station 5, which shows a lower salinity minimum than station 4 nearer the river, may be affected by fresh water seepage from the high bank lying behind it. The high salinity registered at station 8 may be due to evaporation since the locality is apparently not reached by all high tides.

METHODS OF STUDY

The samples were collected by pushing a piece of plastic tubing (internal diameter 3.3 cm.) into the sediment. A constant volume sample one centimeter thick was taken from the upper part of the core using the method described by Walton (1955). The fluid condition of the mud in many cases made it difficult to be certain that equal volume samples were obtained by this method. The area of sediment surface collected, however, was constant. The samples were preserved with buffered formalin and a small quantity of sodium bicarbonate was added, since it has been found that buffered formalin and sea water become increasingly acid with time. Occasional samples giving an acid reaction were discarded before laboratory study. The samples were washed through a



TEXT-FIG. 2—Average frequency distributions (% of living, dead, and total) of foraminiferal species at each station.

sieve (average openings 0.062 mm.), stained with rose Bengal and examined while wet, which is necessary since many specimens of marsh species are destroyed or badly distorted upon drying. It was found that much of the organic detritus could be eliminated by using a pick and then decanting several times.

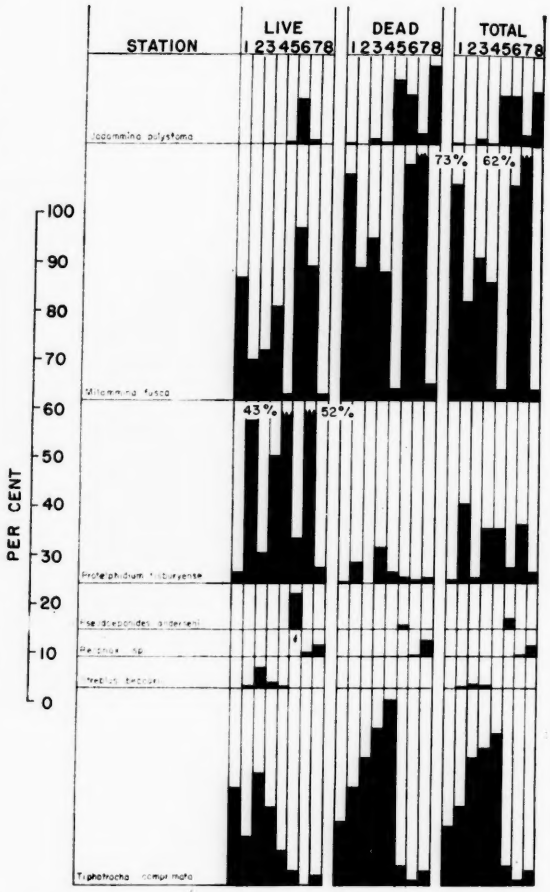
To determine distributional patterns at each station (Text-figs. 2–4) all samples, regardless of season, were averaged. Multiple samples at any one station were averaged first. Each species is plotted in percents of living, dead, and total populations. Occurrences of less than 0.1% are omitted so that a species which may occur very rarely appears to be absent. Some of these rare occurrences are mentioned in the "systematic descriptions."

The data for all stations were averaged to determine the seasonal distributions of the living species. These are given (Text-fig. 5) in numbers of specimens since the area of sampling is constant and it is assumed that the living population is sampled *in toto*.

DISTRIBUTION OF SPECIES

Environmental.—By averaging the data for all seasonal samples taken at each station it is believed that any irregularities of collection are smoothed out and a general picture at any locality obtained. The diagrams (Text-figs. 2–4) include species distributions of dead and total populations, which are of the most interest to the paleontologist, as well as the living populations.

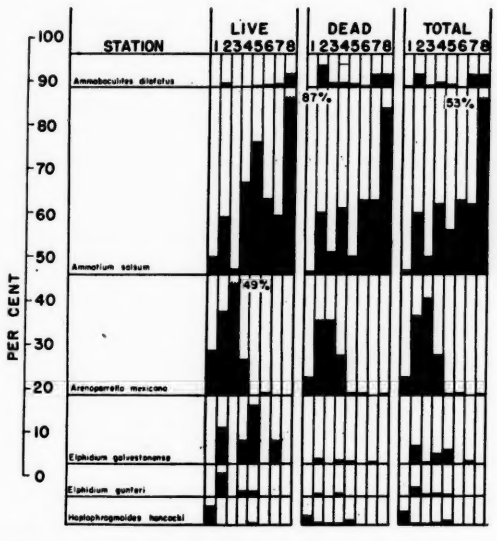
The following generalizations can be made on the distributional patterns, when progressing from the least to the most nearly marine conditions. *Arenoparrella mexicana*, *Haplophragmoides hancocki*, *Tiphotrocha comprimata*, and *Trochammina macrescens*, which form relatively high percentages of the populations at the lower salinity stations, are much rarer at the more marine stations. On the other hand, *Jadammina polystoma*, *Reophax* sp. and *Trochammina inflata*, which are absent or very rare at the low salinity stations, are abundant at the more marine ones. Whether or not these



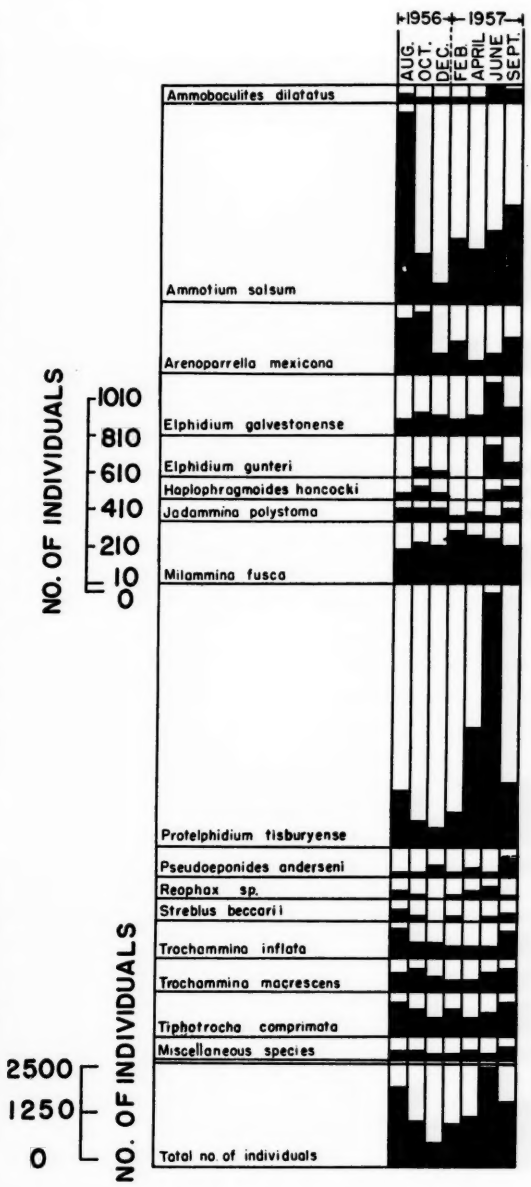
TEXT-FIG. 3—Average frequency distributions (% of living, dead, and total) of foraminiferal species at each station.

differences in distributions are related to differences in salinity conditions is an open question. Other factors may be involved such as changes in vegetation, differences in pH at the sediment surfaces under varying saline conditions, and chemical nutrients or food introduced by the fresh water.

Ammobaculites dilatatus, *Ammotium salsum*, *Elphidium galvestonense*, *E. gunteri*, *Miliammina fusca*, and *Protelphidium tisburyense* appear to fluctuate, for the most part, independently of the salinity or related factors. *Ammotium salsum*, common at most stations, is very abundant at station 8. Perhaps this is due to its apparently high tolerance of varying conditions. It will be noted that it forms a much higher percent of the living population than of the dead population, whereas *Jadammina polystoma* and *Trochammin inflata*, which are fairly abundant in the dead population, form a very small part of the living one. This leads to the speculation that conditions adverse to the latter two species have occurred and the more tolerant form has flourished. The high salinity of 45.2 °/₀₀ found in April is a clue to what one of these adverse conditions may be. *Miliammina fusca*, which occurs at very low frequencies at stations 5 and 8, apparently prefers an environment which is



TEXT-FIG. 4—Average frequency distributions (% of living, dead, and total) of foraminiferal species at each station.



TEXT-FIG. 5—Seasonal frequency distributions (actual number of living specimens) of foraminiferal species at all stations. (Note change of scale after the first 10 individuals.)

periodically exposed because of tidal action. The fluctuations of *Ammobaculites dilatatus*, the two species of *Elphidium*, and *Protelphidium tisburyense* are not easily explained by the known characteristics of the

environments. In general, the three calcarious species follow the same pattern, being present or most common at stations 2, 4, 5, and 7. Thus, they are adapted to both non-marine and near marine conditions and to environments which may or may not be partly exposed due to tidal action.

Of the remaining two species illustrated in the bar diagrams, *Pseudoeponides anderseni* is confined to station 6 (a few dead specimens at station 4) and is discussed more fully in the systematic section; *Streblus beccarii* is too rare in the area for a reliable analysis of its preferences. It is most common at station 3 and was not found at stations 1 and 6–8 suggesting that it prefers intermediate conditions between non-marine and marine. It is possible, however, that marsh environments are not favorable for this species and its distribution is mainly confined to other environments.

In addition, most species appear to favor certain microenvironments. This is discussed further in the section on multiple sampling. The species forming the major part of the faunas at each station are listed in the station descriptions.

Calcareous species.—A study of the bar diagrams (Text-figs. 2–4) shows that the calcareous species are represented for the most part by living specimens. Very few dead ones were observed. This leads to the inference that below the sediment surface, or perhaps even at the sediment-water interface, the pH is sufficiently low to cause the dissolution of the tests. If this condition exists in the "living environment" of the species they must have some mechanism to resist the acidity. Since this implies the expenditure of considerable energy on the part of the organism, it seems more probable that the increase in acidity occurs immediately below the sediment surface, probably due to decaying vegetation, and that it is here that the solution of the tests occurs. It should be remembered that the samples represent only the upper centimeter of sediment so that this supposed acidity increase must occur very near the surface. No reliable measurements have been taken in marsh sediments to show this postulated change in pH across the sediment-water interface. Stewart (1956) found pH values of 7.45 and 6.79 at depths of 15–20 cm. and 23–28 cm. respectively in two marsh cores from San Miguel Lagoon in Baja California. Similar or even lower values have also been observed by others in marsh sediments. Such acidity is more than sufficient to dissolve the calcium carbonate tests.

This rapid solution of the calcareous tests in marsh sediments means that ancient marsh sediments in the sedimentary column may not contain the calcareous species. This must be taken into consideration in interpreting ancient environments by comparison with those of the present day.

Seasonal.—The bar diagram (Text-fig. 5) illustrates the occurrence of living specimens of each species for each season. Some species show a decided increase at certain seasons which suggests that reproduction increases, or mainly occurs, at such times. Examples of this are *Ammotium salsum* (August), *Elphidium galvestonense* (June, September), and *Protelphidium tisburyense* (June). The peak of the standing crop may, of course, have occurred before or after the month where it appears but must have been later than the previous collecting date and before the following one.

Other species such as *Jadammina polystoma*, *Tiphotrocha comprimata*, and *Trochammina macrescens* apparently maintain a fairly steady production, although showing a slight decrease in the winter months. *Miliammina fusca* shows a slight increase in winter. The standing crops taken as a whole are largest in June and lowest in December. An interesting correlation can be made with the temperatures obtaining at these seasons. If the temperatures at the various stations are averaged for each season the results are as follows: August (1956) 24.5°C., October 17.9°C., December 4.9°C., February (1957) 1.6°C., April 17.7°C., June 26.3°C., and September 21.9°C. Thus, during this particular time interval, the standing crop was highest at the time of highest temperature and lowest following the greatest *fall* in temperature, rather than at the time of minimum temperature. Laboratory studies by Myers (1935) and Bradshaw (1955) show that reproduction in certain species increases at higher temperatures and so it may be inferred that the increased standing crop found in summer is due to increased production at that time.

Multiple sampling.—At the final collect-

ing period (September, 1957) triplicate samples were taken at each station, usually within about six inches of each other. This was done to check the reliability of the sampling. The results were very reassuring although occasional discrepancies occurred, usually in the frequency of living specimens of a single species. The total number of living specimens, however, was surprisingly uniform, the larger fluctuations occurring in the numbers of dead specimens. This strengthens the validity of the assumption that the living populations were sampled *in toto*.

A duplicate sample taken near station 5 in December apparently represents a different microenvironment from that of station 5 itself. Unlike the other samples from that station, which were taken in a shallow pool, it was taken from sediment in the *Zostera* growth. The fauna differs in the much larger population of living *Ammotium salsum*, *Haplophragmoides hancocki*, *Miliammina fusca* (previously mentioned as apparently preferring an environment partially exposed during the tidal cycle), and *Trochammina inflata* and the smaller populations of living *Elphidium galvestonense* and *Protelphidium tisburyense*. The environmental factors involved, aside from the partial exposure, may be differences in salinity and other chemical factors (note the unusually low salinity registered at times in the pool at station 5), food supply, competition of rival organisms, etc. A detailed study should be made to define the factors affecting such microenvironmental differences. This would probably involve, in addition to measurements of the physical characteristics, a study of the vegetation and organisms found in the various communities. Bacterial activity is probably of great importance. This particular example also emphasizes the danger of drawing conclusions from isolated samples.

SYSTEMATIC DESCRIPTIONS

Sixteen species which comprise most of the foraminiferal fauna in the area are discussed, together with a brief résumé of the distribution pattern. It should be realized that where the largest living population of any species is said to occur at any given collection it may actually have occurred earlier or later but not as early as the preceding collection or as late as the following one.

In addition, there are a few species (included with "miscellaneous species" in Text-figs. 4, 5) which are worth mentioning. One is a very small, smooth, thin-shelled *Miliolinella* which occurs rarely at stations 3–5 and somewhat more commonly at stations 6 and 8. Like the other calcareous species, most specimens were living. Members of the "*Trochammina squamata*" Parker and Jones group occurred rarely. Occasional specimens of *Saccodendron* were observed in most samples. Thecamoebina were observed at station 1.

The figured specimens have been deposited at the U. S. National Museum, Washington, D. C.

Order FORAMINIFERA
Family REOPHACIDAE
REOPHAX sp.
Pl. 50, fig. 1

This species appears to be new but due to its fragility most of the specimens found were broken. For this reason it is left unnamed until a good suite of material can be obtained. The figured specimen, one of the few unbroken forms, has ten chambers including a relatively large proloculus. The cross section is circular, as is the aperture. The sutures are very slightly depressed and, since the chambers do not increase in size as added, the test is almost straight sided with a bulging proloculus. Length of figured specimen 0.58 mm.

Distribution.—Very rare at many stations but reaches frequencies greater than 0.1% only at stations 7 and 8 (up to 2% of total at station 8). The largest living population appeared to be in June but there were too few living specimens for a reliable statement.

Family LITUOLIDAE
HAPLOPHRAGMOIDES HANCOCKI
Cushman & McCulloch
Pl. 50, figs. 2,3

Haplophragmoides hancocki CUSHMAN & MCCULLOCH, 1939, Allan Hancock Pacific Expeds., v. 6, no. 1, p. 79, pl. 6, figs. 5,6.

This species was described from a sample collected from off the wharf at Ketchikan, Alaska, in which numerous representatives of the Thecamoebina also were found, showing that there must have been contamination by river forms. Reported occurrences

farther south by Cushman & McCulloch should be viewed with some doubt since this species is probably not a truly marine form.

Distribution.—At stations 1–5, most commonly at station 1 (3% of total). The largest living populations were found in September and October, but so few living specimens occurred that this may not be a reliable observation.

AMMOTIUM SALSUM (Cushman & Bronnimann)
Pl. 50, figs. 6,13

Ammobaculites salsus CUSHMAN & BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr., v. 24, p. 16, pl. 3, figs. 7–9.
Ammoscalaria fluvialis PARKER, 1952, Mus. Comp. Zoology, Bull., v. 106, no. 10, p. 444, pl. 1, figs. 24,25.

The specimens are slightly thicker than the types from Trinidad. Parker's (1952) observations that the septa are like those of the genus *Ammoscalaria* Höglund (straight, chitinous) are now believed to be erroneous. Further study shows that although very thin when viewed in clarifying oil, the septa are not straight but curved as in the genus *Ammotium* Loeblich & Tappan.

Distribution.—At all stations, most commonly stations 2, 4–8 (up to 17% of total except at station 3, 53%). The largest living population was found in August, the lowest in December.

AMMOBACULITES DILATATUS Cushman & Bronnimann
Pl. 50, figs. 4,5

Ammobaculites dilatatus CUSHMAN & BRONNIMANN, 1948, Cushman Lab. Foram. Research, Contr. v. 24, p. 39, pl. 7, figs. 10,11.

Specimens were compared with the types by Miss Ruth Todd. She reports (personal communication) that the Poponesset specimens are identical with at least one paratype but otherwise are more inflated. This inflation makes the umbilicus more depressed, the sutures more incised, the chambers more distinct, and the periphery more lobulated. The difference, however, is essentially a minor one and does not seem sufficient for specific or subspecific differentiation.

Distribution.—At all stations, most commonly stations 2, 7, and 8 (3% of total). The largest living population was found in June, the lowest in April. Few living specimens were observed at any time at station 7 which is strange in view of the relatively large dead populations found there. These stations, although subject to a high variation of salinity, are all out of water during part of the tidal cycle.

ARENOPARRELLA MEXICANA (Kornfeld)
Pl. 50, figs 8–10

Trochammina inflata (MONTAGU) var. *mexicana* KORNFELD, 1931, Dept. Geology Stanford Univ., Contr., v. 1, no. 3, p. 86, pl. 13, fig. 5.

The specimens are typical.

Distribution.—At all stations except station 7, most common at stations 1–4 (up to 22% of total). This species apparently prefers the less marine localities. The largest living population was found in October, although the numbers for August were almost as high. There was a considerable increase between December and February after which the numbers dropped off again.

Family TEXTULARIIDAE
TEXTULARIA EARLANDI Parker
Pl. 50, fig. 7

Textularia elegans LACROIX, 1932 (*non Plecanium elegans* HANTKEN, 1868), Instit. Ocean., Monaco, Bull., no. 591, p. 8, text-figs. 4–6.
Textularia tenuissima EARLAND, 1933 (*non. T. tenuissima* HÄUSLER, 1881), Discovery Repts., v. 7, p. 95, pl. 3, figs. 21–30.
Textularia earlandi PARKER, 1952, Mus. Comp. Zoology, Bull., v. 106, no. 10, p. 458 (footnote).

This species is included under "miscellaneous species" in the bar diagrams (Text-figs. 4,5). Its occurrence is of interest since it is found only at stations 6–8, indicating that near marine conditions may be required. No living specimens were found except in September and October.

Family RZEHAKINIDAE
MILIAMMINA FUSCA (Brady)
Pl. 50, figs. 11,12

Quinqueloculina fusca BRADY, 1870, *in* BRADY, G. S., & ROBERTSON, Ann. Mag. Nat. Hist., s. 4, v. 6, p. 286, pl. 11, figs. 2a–c, 3.

There is some variation in the smoothness of the test. Smooth-walled individuals, however, are rare.

Distribution.—An ubiquitous marsh form, occurring at all stations at very high fre-

quencies (up to 62% of total) except at stations 5 and 8 (2%). The latter stations are in shallow pools which are never exposed during the tidal cycle suggesting that the species prefers partially exposed environments. The largest living population was found in February, the smallest in August. The production is presumably fairly high throughout the year to account for the large number of living specimens always present.

Family TROCHAMMINIDAE

TIPHOTROCHA COMPRIMATA (Cushman & Bronnimann)

Pl. 50, figs. 14–17

Trochammina comprimata CUSHMAN & BRONNIMANN, 1948, Cushman Lab. Foram. Research Contr., v. 24, p. 41, pl. 8, figs. 1–3.

Adult specimens have very irregular chambers (figs. 16,17) but the juvenile stages are regular (figs. 14,15).

Distribution.—At all stations, most abundantly at stations 1–5 (up to 31% of total) suggesting that marine conditions are adverse. The largest living populations were found in August and September.

TROCHAMMINA INFLATA (Montagu)

Pl. 50, figs. 18–20

Nautilus inflatus MONTAGU, 1808, Test. Brit., Supp., p. 81, fig. 3.

Distribution.—At all stations except station 1. The highest frequencies are at stations 3, 5, 6, and 8 (up to 30% of total). The largest living population was found in August, the smallest in February, although in April and June living populations were almost as low.

TROCHAMMINA MACRESCENS Brady

Pl. 50, figs. 23–25

Trochammina inflata (MONTAGU) var. *macrescens* BRADY, 1870, *in* BRADY, G. S., & ROBERTSON, Ann. Mag. Nat. Hist., s. 4, v. 6, p. 290, pl. 11, figs. 5a–c.

The possible relationship of this species with *Jadammina polystoma* is discussed under the latter.

Distribution.—Occurs at all stations except station 7. The highest frequencies are found at stations 1–4 (up to 35% of total at station 1) suggesting that this species prefers a non-marine environment. The largest living populations were found from August to October.

JADAMMINA POLYSTOMA Bartenstein & Brand

Pl. 50, figs. 21,22,27

Jadammina polystoma BARTENSTEIN & BRAND, 1938, Senckenbergiana, Band 20, n. 5, p. 381, text-figs. 1–3.

It is possible that this species and *Trochammina macrescens* are related or even identical. *J. polystoma* differs in the less massive test, which is usually more compressed, and in the presence of supplementary apertures on the apertural face. Boltovskoy (1958) postulates that the presence of supplementary apertures on the apertural face of *Protelphidium tisburyense* is a modification due to environmental conditions and does not imply specific difference from specimens without these apertures. It is possible that in a similar manner *J. polystoma* may be a modified form of *T. macrescens* although when the two occur together the adults are easily distinguished. This hypothesis may be tested eventually by culturing in the laboratory.

Distribution.—Rare at stations 1, 3, and 4; somewhat more common at station 7; very common at stations 5, 6, and 8 (up to 11% of total). The species apparently prefers the more marine environments. The largest living populations were found from September to December, but since the number of living specimens was very small even at those times this may not be a reliable observation.

Family ROTALIIDAE

PSEUDOEPONIDES ANDERSENI Warren

Pl. 50, figs. 28–31

Pseudoeponides anderseni WARREN, 1957, Cushman Found. Foram Research, Contr., v. 8, p. 39, pl. 4, figs. 12–15.

Valvulineria sp. PHLEGER & WALTON, 1950, Am. Jour. Science, v. 248, p. 285, pl. 2, fig. 22a,b.

Hofker (1958) suggests that the genus *Pseudoeponides* Uchio is closely related to the genus *Streblus* Fischer. In the Poponesset Bay samples care had to be taken not to mistake specimens of this species for some of the variant forms of *Streblus beccarii.* Especially in wet samples, the dorsal openings are not always immediately observed. *Pseudoeponides anderseni* is also distinguishable by the prolongation of the final chamber which forms a lobe over the um-

bilical region. This resemblance is mentioned here because it seems possible, in view of the few reported occurrences of *E. anderseni*, that it has not been differentiated from *Streblus beccarii* by some workers.

Distribution.—At station 6 (2% of total). A few dead specimens were observed at station 4 (too few to be included in Text-fig. 3). The species seems to prefer environments having near-marine characteristics (minimum salinity at station 6 was 24.8 °/₀₀). Phleger and Walton (1950) found it only in the high marsh at Barnstable, Mass. (minimum salinity 25 °/₀₀). What the other requirements are which confine this species to such a limited occurrence are not known.

Streblus beccarii (Linné)

Nautilus beccarii Linné, 1758, Test. Brit., Supp., p. 710.

Specimens of this species are usually very small, although at station 1 large specimens were found previous to the current collecting period. In general, the marshes in this area do not seem favorable for the development of the species.

Distribution—At stations 2–5 (up to 0.7% of total). The living population was largest in August. Few living specimens were found except in August and September.

Family Elphidiidae
Protelphidium tisburyense (Butcher)
Pl. 50, figs. 26,32

Nonion tisburyensis Butcher, 1948, Cushman Lab. Foram. Research, Contr., v. 24, p. 22, text-figs. 1–3.

This species has a radiate wall structure (personal communication, M. N. Bramlette) and sometimes shows rudimentary retral processes. It is referred to *Protelphidium* because of its affinity with many species referrable to that genus. *Protelphidium* is placed in the family Elphidiidae, although it was originally included with the Nonionidae (Haynes, 1956, p. 86), because the structure of the wall appears to be a fundamental character of more importance in the classification of family groups than such morphological characters as sutural pores or retral processes. As pointed out by Boltovskoy (1958, p. 18) specimens sometimes occur with supplementary apertures on the apertural face, although in Poponesset Bay such specimens are rare and none was observed with more than one such aperture. In counting, however, not every specimen was closely examined for this feature.

Distribution.—At all stations, most commonly stations 2, 4, 5, and 7 (up to 16). It appears to be less adapted to extreme salinities (and/or accompanying factors) being less common at stations 1 and 8. The largest living population was in June, the smallest in December.

Elphidium galvestonense Kornfeld
Pl. 50, figs. 33–35

Elphidium gunteri Cole var. *galvestonensis* Kornfeld, 1931 (part), Dept. Geology Stanford Univ., Contr., v. 1, no. 3, p. 87, pl. 15, fig. 1 (not figs. 2,3).

Elphidium galvestonense Kornfeld, Parker, Phleger & Peirson, 1953, Cushman Found. Foram. Research, Special Pub. 2, p. 7, pl. 3, figs. 15,16.

The specimens are very variable in the amount of inflation of the chambers. In edge view the umbo often appears to be depressed (fig. 34) rather than protruding as in the typical form. Specimens of other species of *Elphidium* may have been included occasionally in the population counts of this species.

Distribution.—At stations 2, 3–5, and 7; most commonly at stations 2, 4, and 5 (up to 4% of total). The largest living population was in June, the smallest in August and February.

Elphidium gunteri Cole
Pl. 50, fig. 36

Elphidium gunteri Cole, 1931, Florida State Geol. Survey, Bull. 6, p. 34, pl. 4, figs. 9,10; Parker, Phleger & Peirson, 1953, Cushman Found. Foram. Research, Special Pub. 2, p. 8, pl. 3, figs. 18,19.

The specimens are usually very small although occasionally larger ones (up to 0.47 mm.) occur. Most of them have about ten chambers in the final whorl instead of 14. In other respects they are typical.

Distribution.—At stations 2–5; most commonly at station 2 (2% of total). The largest living population was in June, with few or no living specimens observed during the rest of the year.

REFERENCES

BOLTOVSKOY, ESTEBAN, 1958, The foraminiferal fauna of the Rio de la Plata and its relation to the Caribbean area: Cushman Found. Foram. Research, Contr., v. 9, p. 17–21, pl. 6.

BRADSHAW, J. S., 1955, Preliminary laboratory experiments on ecology of foraminiferal populations: Micropaleontology, v. 1, p. 351–358.

HAYNES, JOHN, 1956, Certain smaller British Paleocene Foraminifera, Part I: Cushman Found. Foram. Research, Contr., v. 7, p. 79–101, pls. 16–18.

HOFKER, JAN, 1958, The taxonomic position of the genus *Pseudoponides* Uchio, 1950: Cushman Found. Foram. Research, Contr., v. 9, p. 46–48.

MYERS, E. H., 1935, The life history of *Patellina corrugata* Williamson, a foraminifer: Scripps Instit. Oceanography, Univ. California, Tech. ser., v. 3, no. 15, p. 355–392, pls. 10–16.

PARKER, F. L., 1952, Foraminiferal distribution in the Long Island Sound-Buzzards Bay area: Mus. Comp. Zoology, Bull., v. 106, no. 10, p. 428–473, pls. 1–5.

PHLEGER, F. B. & WALTON, W. R., 1950, Ecology of marsh and bay Foraminifera, Barnstable, Mass.: Am. Jour. Science, v. 248, p. 274–294, pls. 1,2.

STEWART, H. B., JR., 1956, Sediments and the environments of deposition in a coastal lagoon: Doctoral Thesis, Univ. of California, Los Angeles, 355 p.

WALTON, W. R., 1955, Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California: Jour. Paleontology, v. 29, p. 952–1018, pls. 99–104.

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PALEONTOLOGICAL NOTES

PREPARATION OF SLIDES FOR SPORES AND OTHER MICROFOSSILS

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INTRODUCTION

The preparation of plant and other acid-insoluble microfossils for microscopic study commonly involves the mounting of chemically processed residues on glass slides. Most paleontologists and laboratories that are engaged in such studies are concerned with modifications in processing and slide-mounting techniques that will result in more economical operations, greater slide durability, and increased ease in microscopy. This review, therefore, summarizes the results of some recent experimentation and experience that may be of general interest to those active in the investigation of plant and animal microfossils. With minor modifications, the conclusions and techniques described in this note apply also to slides used in the study of other finely dispersed materials.

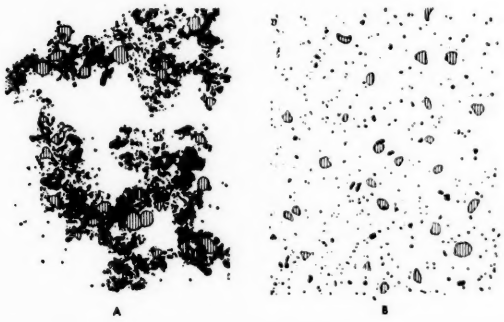
Economy in slide preparation is important both as to the time and the materials that are involved. Preference is shown generally for methods that are not too complex for routine use by only slightly trained technicians, and that provide usable slides as soon as possible after the mounting. The elimination of costly chemicals and of many time-consuming steps, such as the chemical dehydration of residues prior to mounting, is also desirable.

The mounting medium should not become brittle and crack, discolor, or crystallize after an extended period of time. Although the permanent preservation of many of the slides may be unnecessary for commercial laboratories, those prepared from samples having particular value commonly are not differentiated until the subsequent microscopic study. A solid mounting medium that prevents the shifting of the grains on slides has distinct advantages including the ease and precision with which selected specimens can be located for subsequent re-examination. Moreover, the slides then can be filed or stored in a space-saving vertical position in contact with each other, "ringing" or sealing of cover slips is eliminated, and a greater durability for general use and cleaning is obtained. They systematic preservation of all slides, therefore, requires but little effort and space—the immediate availability of a check on previously recorded data is an important advantage.

Mounting media that remain in a viscous state (as glycerin jelly) are favored for some studies on Recent and Pleistocene microfloras because individual specimens may be rotated to change the orientation. Most older fossil microfloras, however, contain flattened specimens so that changes in the orientation are less advantageous.

The scanning of slides and the detailed study and photography of selected specimens become increasingly difficult as the size of the specimens decreases. Experience suggests that the ease and rapidity of paleontologic interpretation of microfloras, therefore, are markedly affected by the amount of effort expended on sample treatment and slide preparation. The relative areas covered by fossil specimens and by mounting medium on slides should be such that discrete particles are neither crowded nor too widely scattered (Text-fig. 1). A uniform and acceptable compromise can be obtained generally by experimentation and practice.

A second attribute that facilitates microscopy is the concentration of specimens along a single focal plane; this eliminates the inconvenience of continual refocusing as a slide is scanned. Moreover, the tendency to neglect out-of-focus specimens is eliminated when all specimens lie along one plane. A convenient method to obtain a flat layer of specimens is to mount a thin film of the residue directly on to the cover slip. After the film has hardened, the slip is inverted and is attached to a slide. Inasmuch as the layer of fossils then lies immediately adjacent to the under side of the cover slip, an excessively thick layer of mounting ma-



TEXT. FIG. *1*—Views of typical areas of slides prepared from the same residue and showing the relative dispersal of acid-insoluble microfossils (vertically lined) and associated organic fragments and debris (black). The microfossil assemblage that was obtained from this sample was poorly preserved and was associated with a considerable amount of fragmentary spores, pollen, and cuticle. ×60.
A. Slide mounted using a non-dispersing film-former.
B. Slide mounted using a dispersing film-former (hydroxyethyl cellulose).

terial does not impede use of objectives having a very short focal length.

Slides prepared from residues containing many very small particles also need good dispersal, but some residues are very difficult to mount satisfactorily because they tend to clump or flocculate, partly because of induced electrical charges and mass attraction. The medium in which the residues are applied to the cover slip, therefore, should have moderately strong dispersing properties.

MOUNTING MEDIA AND METHODS

Several different methods of mounting microfossil residues have relatively wide current use. Most of these comprise a single layer of Canada balsam, diaphane, glycerin jelly, or other material mixed with the residue between the slide and cover slip. The glycerin types of media do not set firmly, and the resulting slides are difficult to preserve and file. Media such as Canada balsam and diaphane cannot be mixed directly with aqueous residues; this type of mounting material generally requires an appreciable interval before the slides are ready for use because they set by the release of solvents. Slides prepared with Canada balsam are usually considered as being permanent, but discoloration and fragility seem to have developed in many of the older slides. The mixing of the residue and the mounting medium also results in the occurrence of specimens at many different levels.

Although most of the described mounting methods and media have advantageous features, the two-layer mounting method using substances described in this report seems to be more satisfactory for the general preparation, use, and preservation of slides.

Experimentation with a number of different products that were suggested by chemists in the Production Research Division, Humble Oil & Refining Co., indicated that "Cellosize" (a powdered hydroxyethyl cellulose manufactured by the Union Carbide Chemicals Company) forms an eminently satisfactory film. A solution of this "nonionic, water-soluble ether of cellulose" (Anon., 1957) acts both as an excellent dispersing agent and as a thin film-former. The hydroxyethyl cellulose (HEC) is water soluble so that aqueous residues do not need to be dehydrated by treatment with organic solvents, and the film adheres firmly to both the glass and the plastic used in mounting. Several varieties of HEC are available for obtaining a range from low to high viscosity, but most satisfactory results have been obtained with a two-percent solution of a low-viscosity powder (No. WP-09). A solution of the powder (which tends to flocculate when added directly to water) is obtained readily by first saturating a measured quantity of powder with a small amount of methyl alcohol as a wetting agent and then adding a measured volume of distilled water. The mixture is dissolved rather rapidly by heating and stirring; the heat also removes the

alcohol which is no longer necessary in the solution. Filtering is necessary to eliminate small, insoluble, fibrous particles.

PREPARATION OF SAMPLES AND SLIDES

The chemical maceration of samples to obtain microfloras and associated acid-insoluble microfossils generally follows the methods that have been described by many workers (Kosanke, 1950; Kuyl, Muller, & Waterbolk, 1955; Norem, 1956; Sittler, 1955; and Wilson, 1944; 1946).

The basic phases in the maceration process include

1. Solution of carbonates using HCl or other acid.
2. Solution of other mineral matter using H_2F_2.
3. Partial oxidation of organic matter using Schultze's solution ($HNO_3 + KClO_3$) or other chemical.
4. Dispersal of humic acids using KOH or other base.

Following the chemical treatment, samples are stained with an aqueous safranine solution or with a similar biological stain. After water-washing the residue to remove excess stain, the sample is ready for mount.

For convenience and to avoid labeling errors, the blank glass slides may be laid out in a flat rack and labeled (as with waterproof ink on a frosted end). A small drop of water is put on each slide, and a clean cover slip is placed on the drop. The water provides for the temporary attachment of the cover slip to the slide.

A few drops of the aqueous residue are drawn off by means of a slender pipette and, with a few drops of the prepared HEC solution, are placed in a small beaker or shell vial. The volumes of liquids that are needed depend on the area of the cover slip and on the number of slides that are to be mounted. The relative quantity of HEC solution, moreover, depends on the desired concentration of the particles and can be estimated more or less reliably with a minimum of experience. After thorough mixing by an air jet through the pipette, one or two drops are placed on the cover slip. By careful manipulation of the pipette the viscous mixture can be spread evenly over the entire surface of the cover slip. The high surface tension prevents the mixture at the edges from flowing onto the slide. If inspection or a rapid microscope examination of the first slide indicates that the residue is too dilute or too concentrated, more of the original residue may be added or a portion may be drawn off by means of the pipette.

After a group of cover slips has been prepared, they are dried on a hotplate or in an oven (generally 1 hour at about 60°C.). The disappearance of the water drop beneath the cover slip suggests that sufficient dryness has been attained. Each dried cover slip then is removed carefully, inverted, and replaced on the cleaned slide over a drop of clear thermo-setting plastic (mixed with plasticizer but not with the accelerator). Polyester types of liquid casting materials, such as "Castolite" and "Bio-Plastic," seem to have advantages, but other media may be used. A needle aids in moving the cover slip to the proper position. Touching the slide to a hotplate for an instant will cause the plastic to flow rapidly to the edges if a complete seal was not obtained at first. After the mounted slides have been returned to the drying oven for about an hour, they are ready for use or for filing. Slides needed for immediate use can be prepared in a similar manner except that careful heating on a hotplate permits the finishing of slides in only a few minutes.

Other organic compounds can be used to form the thin films in the initial mounting process. Some of these, however, have essentially no dispersing properties and others, such as sodium carboxymethyl cellulose, may contain salts that tend to form crystals. The hydroxyethyl cellulose, which is preferred as the residue-binding film in the two-layer mounts, is reported to be clear, colorless, and insensitive to light; films had "good clarity and freedom from yellowing after being stored at room temperature for ten years." (Anon., 1957).

The two-layer mounts also are advantageous for dispersing and mounting alcyonarian spicules and similar small fossil fragments. Preliminary testing suggests, moreover, that wet or dry samples of mineral grains, soils, and other materials can be dispersed on glass slides and covered by essentially the same technique as has been described for the microfossils.

The index of refraction of the hydroxy-

ethyl cellulose film is approximately 1.50 to 1.51; the "Castolite" plastic has an index of about 1.531.

REFERENCES

ANONYMOUS, 1957, "Cellosize" hydroxyethyl cellulose: Union Carbide Chemicals Co., Advance Tech. Inf., 12 p.

KOSANKE, R. M., 1950, Pennsylvanian spores of Illinois and their use in correlation: Illinois Geol. Survey, Bull. 74, 128 p., 18 pls.

KUYL, O. S., MULLER, J. & WATERBOLK, H. T., 1955, The appliction of palynology to oil geology, with special reference to western Venezuela: Geologie en Mijnbouw, n.s., v. 17, p. 49–76, pls. 1–8.

NOREM, W. L., 1956, An improved method for separating fossil spores and pollen from siliceous rocks: Jour. Paleontology, v. 30, p. 1258–1260.

SITTLER, CLAUDE, 1955, Méthodes et techniques physico-chimiques de préparation des sédiments en vue de leur analyse pollinique: Inst. Francais Pétrole Rev., v. 10, p. 103–114.

WILSON, L. R., 1944, Spores and pollen as microfossils: Botanical Rev., v. 10, p. 499–523.

——, 1946, The correlation of sedimentary rocks by fossil spores and pollen: Jour. Sed. Petrology, v. 16, p. 110–120.

THE QUESTIONABLE AGE OF THE AQUIA FORMATION

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During the course of a study of the Foraminifera of the Bright seat formation (Danian) of Maryland and its correlation, attention was drawn to the problem of the age of the overlying Aquia formation. This formation for a considerable time has been thought to be of Lower Eocene age and generally has been correlated with the Wilcox Eocene of the Gulf Coastal Plain.

Recently Loeblich & Tappan (1957) advocated an Upper Paleocene age on the basis of the planktonic Foraminifera collected at the type locality of the Aquia formation. Further studies by the author appear to be in agreement with their dating.

The Aquia formation outcrops in a belt across Maryland and Virginia. It unconformably overlies the Brightseat formation of lowermost Paleocene age, where the latter is present. Otherwise, it unconformably overlies the Upper Cretaceous Monmouth formation. This is caused either by overlap or by intermediate erosion of the Brightseat formation. The contact is marked by a zone of phosphatic pebbles and in places by quartz pebbles up to 4″ in length.

The lithologic differences between the Aquia and the underlying formations are sharp, and the basal contact is readily recognizable in the field. The Aquia formation is a green sand and in the basal portions contains coarse grains of glauconite which are lacking in the Brightseat and Monmouth formations.

The Aquia formation is overlain by the Nanjemoy formation. The contact is marked by a sharp lithologic break from the green sand of the Aquia into a pink clay representing the Nanjemoy. The age of the Nanjemoy is not known with certainty, but Cooke (1952) correlates it with the Wilcox.

The Aquia formation was considered originally a stage of the Pamunkey formation, which was named by Darton in 1891. Clark & Martin (1901) raised the Aquia to formational rank and elevated the Pamunkey to a group which includes the Aquia and the Nanjemoy formations. Gildersleeve (1942) gives an excellent summary of the Aquia formation up to that time.

Cooke, Gardner, & Woodring (1943) correlated the Aquia with the Ackerman, Nanafalia, and Salt Mountain formations of Mississippi and Alabama and with the Hornerstown and Vincentown formations of New Jersey. They considered all of these to be of Ypresian age.

Cushman (1944) described a foraminiferal fauna from the Aquia close to the type locality in Virginia. He stated that the fauna "definitely places the age of these beds as Wilcox Eocene."

Shifflett (1948) described Aquia foraminiferal faunas from Virginia and Mary-

land and considered them to reflect a Ypresian and Cuisian age, which would include "essentially all of the Wilcox except the upper most part."

It will be shown that the correlations by Cushman & Shifflett were based on erroneous assumptions and that the conclusion of a Wilcox age for the Aquia formation is not warrented from their studies.

Schmitt (1948) on the basis of a study of the Aquia ostracods felt that they supported correlations of the Aquia "with the Hornerstown marl of New Jersey and the Wilcox group of the Gulf Coast". Philip Brown (personal communication), after a study of the Aquia ostracods from water wells in North Carolina, feels that they indicate a Paleocene age. Olsson (1958) has shown that the Hornerstown formation includes Paleocene sediments equivalent to the Danian and Thanetian.

Cooke (1952) correlates the Aquia with the basal Nanafalia formation of Alabama on the basis of the mollusk *Ostrea compressirostra* Say. Cooke (1952) lists the following mollusks as having been collected from the Aquia and reports their collection (U.S.G.S. 17147) from:

Head of branch one mile southwest of Brithtseat, C. W. Cooke and H. K. Brooks collectors.

Lunatia marylandica Conrad
Turritella humerosa Conrad
Cucullaea gigantea Conrad
Ostrea compressirostra Say
Dosiniopsis lenticularis (Rogers)
Callocardia pyga (Rogers)
Lucina sp.
Macoma? sp.
Crassatella sp.
Corbula subengonata Dall
Venericardia planicosta regia Conrad

The Aquia formation does not outcrop at this locality. Here the Monmouth formation is overlain by the Brightseat formation which is in turn overlain by alluvium. As a double check that these mollusks were recovered from the Brightseat formation, the matrix of the specimens from U.S.G.S. collection 17147 were examined and found to contain diagnostic Brightseat species of Foraminifera, including *Globigerinoides daubjergensis* (Bronnimann) and *Globorotalia compressa* Plummer. No species diagnostic to the Aquia formation was found. The presence of these mollusks in the Aquia formation from other localities can not be used as the basis for correlation of the Aquia to strata of Wilcox equivalency, due to their presence in beds of known Paleocene age.

Loeblich & Tappan (1957) record twenty-four species of planktonic Foraminifera from the Aquia formation and on the basis of the presence of *Globorotalia angulata* (White), *G. acuta* Toulmin and *Globigerina spiralis* Bolli place the Aquia formation in the *Globorotalia velascoensis-G. acuta-Globigerina spiralis* subzone of the *Globorotalia angulata* zone which they consider of Upper Paleocene age.

Loeblich & Tappan (1957) made the following corrections of Shifflett's planktonic determinations:

1. *Globigerina* cf. *ouachitaensis* Howe & Wallace = *G. spiralis* Bolli.
2. *G.* cf. *G. pseudobulloides* Plummer = *Globorotalia perclara* Loeblich & Tappan.
3. *G. membranacea* (Ehrenberg) = *G. pseudomenardii* Bolli.
4. *G. wilcoxensis* Cushman & Ponton = *G. aequa* Cushman & Renz.
5. *Guembelina wilcoxensis* Cushman & Ponton = *Chiloguembelina crinita* (Glaessner).

The foraminiferal fauna described by Cushman from the Aquia formation contained 44 species. Twenty-two of these are not diagnostic, having been identified as sp? or cf. Some are new species not recorded elsewhere. Others are catch-all units that range throughout the Tertiary or have been previously recorded only from Recent sediments.

Seventeen species are common to both the Midway and the Wilcox.

Four species were identified erroneously as diagnostic Wilcox species and are corrected as follows:

1. *Lamarkina wilcoxensis* Cushman = *Ceratobulimina perplexa* Plummer. This species is not known to occur in sediments younger than Paleocene age.
2. *Valvulinaria wilcoxensis* Cushman & Ponton = new species. Comparison of Cushman's specimens from the Aquia formation do not compare with the primary types of *V. wilcoxensis*. The latter are biumbilicate, while the Aquia specimens have a very convex spiral side which lacks an umbilicus.
3. *Valvulinaria scrobiculata* (Schwager) = *Gyroidina soldanii* var. *octocamerata* Cushman & Hanna. The Aquia specimens do not compare with Schwager's original figures. Toul-

min (1941) placed *Valvulinaria scrobiculata* Cushman & Ponton (not Schwager) into synonomy with *Gyroidina soldanii* var *octocamerata* Cushman & Hanna. This species is known from the Midway as well as the Wilcox. No true *Valvulinaria scrobiculata* (Schwager) have been reported from North America.

4. *Darbyella wilcoxensis* Cushman = *Robulus midwayensis* Plummer. The specimens from the Aquia are varients of *R. midwayensis* which have uncoiled. Similar forms are common in the Brightseat formation where *R. midwayensis* is present in great abundance. This species when studied in terms of the population exhibits considerable variation and it is possible to show all the intermediate types between the "*Darbyella wilcoxensis*" variants and the typical *Robulus midwayensis*.

Cushman's fauna offers no basis for a Wilcox correlation of the Aquia formation as it does not contain any diagnostic Wilcox species, on the contrary it does contain *Ceratobulimina perplexa* and *Robulus midwayensis* which are considered to be diagnostic Paleocene species.

Shifflett (1948) cites 89 species of Foraminifera from the Aquia formation. Forty-eight of these are not diagnostic, recorded as sp.? (15), cf. (7), or else new species (6), species not recorded elsewhere (3), catch-all species ranging throughout the Tertiary (3), Recent forms (13) or Cretaceous (1).

Twenty species are common to both the Midway and the Wilcox and are not diagnostic. Two species are known only from the Paleocene. *Citharina plumoides* (Plummer), recorded from the Aquia by Shifflett, is considered an excellent guide fossil for the Paleocene. *Cibicides neelyi* Jennings is known from the Hornerstown formation of New Jersey which contains sediments of Danian and Thanetian age.

Nine species are planktonic and have been included in Leoblich & Tappan's (1957) study. These nine species together with fifteen other planktonic species reported by them indicate a Paleocene age as none of these are considered to be diagnostic of the Wilcox.

Ten species are reported by Shifflett to be diagnostic of the Wilcox. They are corrected as follows:

1. *Lamarkina wilcoxensis* Cushman = *Ceratobulimina perplexa* Plummer.
2. *Valvulinaria wilcoxensis* Cushman & Ponton = new species.
3. *V. scrobiculata* (Schwager) = *Gyroidina soldanii* var. *octocamerata* Cushman & Hanna. These were previously discussed.
4. *Angulogerina parvula* (Cushman & Thomas). This species occurs in the Soldado rock formation of Trinidad, which is of Paleocene age.
5. *Pulvinulinella danvillensis* Howe & Wallace. This species is abundant in the Brightseat formation.
6. *Nonion planatum* Cushman & Thomas = new species. The specimen deposited in the U. S. National Museum collection by Shifflett does not compare with the holotype of *Nonion planatum* which is very small, very compressed, with ten chambers and an acute periphery. Shifflett's specimen has eight inflated chambers and a round periphery. It is probably a new species and is not diagnostic of a Wilcox age.
7. *Robulus knighti* Toulmin = *R. midwayensis* Plummer. The specimens of Shifflett compare well with the variants of *R. midwayensis* from the Brightseat formation.

Three species of the Polymorphinidae, *Globulina munsteri* (Reuss), *Polymorphina advena* Cushman var. *nuda* Howe and Roberts, and *Sigmomorphina semitecta* (Reuss) are cited by Shifflett to occur in the Aquia formation, these species are not known from the Paleocene and are the only species in Shifflett's fauna that would indicate a Wilcox age for the Aquia formation.

Shifflett records the presence of *Bulimina* cf. *cacumenata*. Careful examination of her specimens and comparison with the holotype shows that it is *Bulimina cacumenata* Cushman & Parker, which is considered an excellent guide fossil for the Paleocene.

The presence of such diagnostic species as *Ceratobulimina perplexa*, *Citharina plumoides*, *Robulus midwayensis*, and *Bulimina cacumenata* coupled with the strong evidence furnished by Leoblich & Tappan's study of the planktonic species would seem to more than balance the three Eocene(?) Polymorphinidae and indicate a Paleocene age for the Aquia formation.

It is hoped that this brief discussion of the Aquia formation will re-open the question of its age and stimulate interest in a more detailed study of the various faunas. The Mollusks have not been critically examined since the early 1900's and should be re-examined in the light of more recent information, this is also true of the ostracods and Foraminifera.

REFERENCES

CLARK, W. B., & MARTIN, G., 1901, The Eocene Deposits of Maryland: Maryland Geol. Survey, Eocene volume.

COOKE, C. W., 1952, Geology and Water Resources of Prince Georges County: Maryland Dept. Geology, Mines and Water Resour., Bull. 10.

COOKE, C. W., GARDNER, J., & WOODRING, W., 1943, Correlation of Cenzoic Formations of the Atlantic and Gulf Coastal Plain and the Caribbean Region: Geol. Soc. America, Bull., v. 54, p. 1713–1723.

CUSHMAN, J., 1944, Foraminifera from the Aquia Formation of Virginia: Contr. Cushman Lab. Foram. Res., v. , p. 17.

GILDERSLEEVE, B., 1942, Eocene of Virginia: Virginia Geol. Survey, Bull. 57.

LOEBLICH, A., & TAPPAN, H., 1957, Correlation of the Gulf and Atlantic Coastal Plain Paleocene and Lower Eocene Formations by means of Planktonic Foraminifera, Jour. Paleontology, v. 31, p. 1109–1137.

OLSSON, R., 1958, Late Cretaceous-Early Tertiary Stratigraphy of New Jersey, Unpublished Thesis, Princeton University.

SCHMITT, R., 1948, Ostracoda from the Upper Cretaceous and Lower Eocene of Maryland, Delaware and Virginia, Jour. Paleontology,v. 22, p. 389–431.

SHIFFLETT, E., 1948, Eocene Stratigraphy and Foraminifera of the Aquia Formation, Maryland Dept. Geology, Mines and Water Resources, Bull. 3.

TOULMIN, L., 1941, Eocene smaller Foraminifera from the Salt Mountain limestone of Alabama, Jour. Paleontology, v. 15, p. 567–611.

SOCIETY RECORDS AND ACTIVITIES

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

Program for S.E.P.M. Dallas Meeting

W. M. Furnish, Technical Program Chairman

RESEARCH COMMITTEE SYMPOSIUM: CONCEPTS OF STRATIGRAPHIC CLASSIFICATION AND CORRELATION

1. INTRODUCTION, Grover E. Murray, Louisiana State University, Baton Rouge, Louisiana
2. THE CLASSIFICATION CONTROVERSY, Hollis D. Hedberg, Gulf Oil Corporation, Pittsburgh, Pennsylvania
3. MEANING OF CORRELATION, John Rodgers, Yale University, New Haven, Connecticut
4. STRATIGRAPHIC UNITS IN TIME AND SPACE, Harry Wheeler, University of Washington, Seattle, Washington
5. PROBLEMS OF STRATIGRAPHY AND CORRELATION OF PRECAMBRIAN ROCKS WITH PARTICULAR REFERENCE TO THE LAKE SUPERIOR REGION, Harold L. James, U. S. Geological Survey, Washington, D. C.
6. NORTH AMERICAN CAMBRO-ORDOVICIAN BIOSTRATIGRAPHY—LAYER CAKE GEOLOGY?, James L. Wilson, Shell Development Company, Houston, Texas
7. THE ROLE OF FOSSILS IN DEFINING ROCK UNITS IN THE DEVONIAN OF WESTERN AND ARCTIC CANADA, Digby McClaren, Geological Survey of Canada, Ottawa, Ontario, Canada
8. SEPARATION OF STRATA: PALEOZOIC LIMESTONES OF THE WILLISTON BASIN, A. D. Cumming, Tidewater Oil Company; J. G. C. M. Fuller, Amerada Petroleum Corporation; and J. W. Porter, Canadian Superior Oil Company of California; Regina, Saskatchewan, Canada
9. TECHNIQUES OF MOLLUSC ZONATION IN THE TEXAS CRETACEOUS, Keith Young, University of Texas, Austin, Texas
10. CYCLIC CORRELATION IN THE TEXAS COMANCHE CRETACEOUS, Frank E. Lozo, Jr., Shell Development Company, Houston, Texas
11. PROVINCIAL TIME-ROCK NOMENCLATURE IN THE GULF CRETACEOUS, HELP OR HINDRANCE?, C. O. Durham, Jr., Louisiana State University, Baton Rouge, Louisiana
12. MAMMALIAN BIOSTRATIGRAPHIC ZONES IN THE CONTINENTAL TERTIARY, John A. Wilson, University of Texas, Austin, Texas

STRATIGRAPHY AND SEDIMENTARY PETROLOGY

1. STRATIGRAPHY AND DEPOSITIONAL TECTONICS OF THE NORTH YUKON-LOWER MACKENZIE AREA, L. J. Martin, The British American Oil Company Ltd., Calgary, Alberta, Canada
2. PETROLOGY OF THE LYONS FORMATION ALONG THE FOOTHILLS OF THE COLORADO FRONT RANGE, John F. Hubert, University of Missouri, Columbia, Missouri
3. PETROLOGY AND PROVENANCE OF THE CRETACEOUS SEDIMENTS OF THE UPPER MISSISSIPPI EMBAYMENT, Wayne A. Pryor, Illinois Geological Survey, Urbana, Illinois

4. PARAMETERS OF SEDIMENTATION IN TAMPA BAY, FLORIDA, H. G. Goodell and D. S. Gorsline, Florida State University, Tallahassee, Florida
5. CATENA, A NEW TERM IN STRATIGRAPHIC NOMENCLATURE, A. J. Crowley and Allen C. Tester, State University of Iowa, Iowa City, Iowa
6. LITHOTOPIC RELATIONSHIPS IN DEEP WATER TROUGHS, Keith A. W. Crook, University of New England, Armidale, New South Wales, Australia

REEF CARBONATES

1. MISSISSIPPIAN BIOHERMS OF SOUTHWESTERN UNITED STATES, L. C. Pray and A. S. Horowitz, The Ohio Oil Company, Denver Research Center, Littleton, Colorado
2. ORIGIN OF SOME PENNSYLVANIAN ALGAL BIOHERMS IN SOUTHWESTERN UNITED STATES, J. L. Wray, The Ohio Oil Company, Denver Research Center, Littleton, Colorado
3. PERMIAN McCLOUD LIMESTONE OF NORTHERN CALIFORNIA, J. W. Harbaugh, Stanford University, Stanford, California
4. THE JAMESON REEF, WEST TEXAS, Carel Otte, The Pure Oil Company Research Center, Crystal Lake, Illinois
5. A LATE TRIASSIC REEF IN THE NORTHERN ALPS, Henry Ohlen, Princeton University, Princeton, New Jersey

GENERAL PALEONTOLOGY AND STRATIGRAPHY

1. PALYNOLOGY OF THE CABANISS COALS IN HENRY COUNTY, MISSOURI, Robert E. Schmieg, University of Missouri, Columbia, Missouri
2. APPLICATION OF STATISTICS TO THE CORRELATION OF COAL BEDS BY MEANS OF MIOSPORE ASSEMBLAGES, Henry H. Gray and G. K. Guennel, Indiana Geological Survey, Bloomington, Indiana
3. BIOSTRATIGRAPHY OF THE CRETACEOUS OF NORTHERN ALASKA, Helen Tappan, University of California, Los Angeles, California
4. UPPER ORDOVICIAN CONODONTS FROM HUDSON BAY AREA, R. L. Ethington, Arizona State College, Tempe, Arizona, and W. M. Furnish, State University of Iowa, Iowa City, Iowa
5. STRATIGRAPHIC POSITION OF THE WELLINGTON CONCHOSTRACAN BEDS IN KANSAS, Paul Tasch, University of Wichita, Wichita, Kansas
6. MIDDLE MISSISSIPPIAN AMMONOIDS OF THE EASTERN INTERIOR, A. K. Miller and W. M. Furnish, State University of Iowa, Iowa City, Iowa
7. THE MISSISSIPPIAN SYSTEM IN NORTHERN AND CENTRAL NEW MEXICO, Augustus K. Armstrong, University of Cincinnati, Cincinnati, Ohio
8. MISSISSIPPIAN-PENNSYLVANIAN CONTACT IN THE ROCKY MOUNTAIN REGION, Allen C. Tester, State University of Iowa, Iowa City, Iowa

MINERALOGY AND SEDIMENTARY PETROLOGY

1. APPLICATION OF DATA PROCESSING METHODS TO GEOLOGICAL PROBLEMS, Margaret A. Parker, Illinois Geological Survey, Urbana, Illinois
2. HIGH SPEED DIGITAL COMPUTERS IN THE STATISTICAL ANALYSIS OF SEDIMENTARY AND STRATIGRAPHIC DATA, W. C. Krumbein, Northwestern University, Evanston, Illinois
3. HYDRAULIC EQUIVALENT SIZES OF HEAVY MINERALS, Louis I. Briggs, University of Michigan, Ann Arbor, Michigan
4. INTERACTION OF SOURCE AND ENVIRONMENT IN CONTROLLING PLOTS OF SIZE VERSUS SORTING, Robert L. Folk, University of Texas, Austin, Texas
5. EXPERIMENTAL ABRASION AND FROSTING OF SAND GRAINS, Ph. H. Kuenen, Geologisch Instituut, Groningen, Netherlands
6. THE ROLE OF DIAGENESIS IN SANDSTONE-TYPE URANIUM DEPOSITS, Alice D. Weeks, U. S. Geological Survey, Washington, D. C.
7. SEDIMENTARY PETROLOGY AND ORE GENESIS, G. C. Amstutz, Missouri School of Mines, Rolla, Missouri

FIELD TRIPS

The annual technical and business meeting of the Permian Basin Section, Society of Economic Paleontologists and Mineralogists, will be held Thursday, April 16, 1959. Headquarters for the meetings and for the evening banquet will be the Desert Aire Motel, Alamogordo, New Mexico. General Chairman is M. Russell Stripp, Standard Oil Company of Texas, Box 746, Roswell, New Mexico. Chairman of the technical pro-

gram is Richard F. Meyer, Humble Oil & Refining Company, Box 1287, Roswell, New Mexico.

A field trip on the west slope of the Sacramento Mountains, New Mexico, is planned for Friday and Saturday, April 17 and 18, 1959, under the leadership of Lloyd C. Pray, The Ohio Oil Company, Box 269, Littleton, Colorado. This trip will be sponsored jointly by the Permian Basin Section, Society of Economic Paleontologists and Mineralogists, and the Roswell Geological Society. Field Trip Chairmen are Carl Ulvog, Wilco Building, Midland, Texas, and Frank Packard, Box 1287, Roswell, New Mexico. Registration for the field trip will be on Thursday, April 16, 1959, at the Desert Aire Motel, Alamogordo, New Mexico.

Details of the technical session and field conference will be announced later.

The annual field trip of the Pacific Section, Society of Economic Paleontologists and Mineralogists, will be held Friday and Saturday, April 24 and 25, 1959. Registration and a dinner meeting will be held on Friday, 6:30 P.M., at the Brookdale Lodge, Boulder Creek, California. Earl Brabb, Stanford University, will speak on the "Stratigraphy of the Boulder Creek area, Santa Cruz Mountains, California." The caravan for the field trip will assemble Saturday, April 25, 8:00 A.M., at the Brookdale Lodge. Tertiary sedimentary rocks in the Boulder Creek area, Santa Cruz Mountains, will be the subject of the trip, which will be under the leadership of Earl Brabb.

The field trip committee consists of Charles Carey, Union Oil Company; A. A. Almgren, The Superior Oil Company; Earl Brabb, Stanford University; Weldon Rau, U. S. Geological Survey; and Richard L. Pierce, Richfield Oil Company.

ASTOGENETIC STUDY OF FISTULIPOROID BRYOZOANS: CORRECTION

T. G. PERRY AND DONALD E. HATTIN
Indiana University, Bloomington, Indiana

The numerals of the figures on Plates 130 and 131 of Volume 32 of this *Journal* inadvertently were removed in preparation for publication.

Numerals should be inserted beneath illustrations on Plate 130 as follows: *1*, top left; *2*, left center; *3*, lower left; *4*, top right; *5*, right center; and *6*, lower right.

Numerals should be inserted beneath illustrations on Plate 131 as follows: *1*, top left; *2*, top center; *3*, lower left; *4*, top right; *5*, left center; and *6*, lower right.

Also, the first sentence of the second paragraph on page 1049 of Volume 32 of this *Journal* should read "The development of the *Dybowskiella* zoaria contrasts greatly with zoaria of ramose trepostomatous bryozoans."

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